MCA-527

Digital Multi-Channel Analyzer

User Manual

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1 Introduction

The MCA527 is a battery powered high performance 16K multi-channel analyzer / multi-channel scaler module. High voltage supply for detector and preamplifier power supply are integrated as well as an internal coarse amplifier, an analog-digital converter and digital signal processing. Together with a small detector it forms a pocket-size gamma spectroscopy system and timer / counter, which is well suited to the demands of field measurements for international safeguards, environmental monitoring, nuclear waste treatment facilities, radioactive transport control and similar applications.

Furthermore, the MCA527 supports a vast number of different detectors and its 16k resolution is adequate to support high resolution gamma spectrometry with HPGe detectors.

The Mini MCA software allows to operate the device as a general purpose multi-channel analyzer (e. g. with WinSPEC) and multi-channel scaler analyzer (e. g. WinMCS). Additional user programs which support safeguards specific applications as U235 enrichment verification, spectral radiation survey meter mode supporting active length determination are available. See chapter 6 for more information.

The appendixes[1] contain descriptions for users who want to develop own software for the MCA527.

The MCA527 firmware can be updated by the user himself. New firmware versions and the program for this can be downloaded from our web pages.

The MCA527 is also available as downgraded version MCA527L. Everything not essential for medium and low resolution detectors is omitted here. Restrictions for MCA527L are mentioned in the text of this manual where applicable.

For applications where MCA functionality must be embedded into customer devices or systems, different OEM versions of the MCA527 are available. This simple PCB boards are software compatible with the standard version but limited in performance and functionality.

1 The appendixes relevant for developers are only available in the full version of this manual.

1.1 General Introduction into Gamma Spectroscopy

The main application of gamma spectroscopy is to measure the radiation emitted from decaying radionuclides and from this conclude on the type and quantity of isotopes present. In most cases, the gamma radiation is most suitable to distinguish between different radioisotopes. Gamma radiation consists of photons, similar as light. But whereas the typical photon energy for visible light is 1eV ($1.6*10^{-19}$ Joule) the gamma photon energy from radioactive decay is much higher and typically between 3keV and 3MeV. For measuring this gamma radiation a suitable detector is needed. This can be a semiconductor detector, which converts an absorbed photon directly into a small charge quantity. Or it can be a scintillation detector, which converts an absorbed photon into visible light, which is then converted by a photomultiplier into a charge. After the preamplifier, which is usually integrated within the detector, the charge appears as voltage step on the output signal, see also figures 6 and 7.

The task of the multi-channel analyzer is now to measure the amplitude of these voltage steps with best possible accuracy and make a histogram of all measured amplitude values. This is called pulse height analysis (PHA) mode.

The second most important operation mode is to record count rate in dependence of time, using defined time channels. This is called multichannel scaling (MCS) mode. Various other measurement modes are possible and described later in this manual.

2 Hardware

2.1 Safety Information

Read all these instructions first!

Save these instructions for later use.

Do not remove connectors during operation

To avoid personal injury or damage of equipment, do not remove the connectors for the high voltage supply, preamplifier supply, and the input connector until the high voltage is shut down and the device is switched off at least for 1 minute.

Do not open the device when it is turned on

Do not open the device before the power is switched off.

2.1.1 Power Source

This device is intended to operate from an internal accumulator set (high performance Li-Ion battery) or together with an external wall adapter. Furthermore the device can be powered directly from a high power USB port (up to the maximum nominal input power of 2.5W).

The supply voltage for the MCA is nominal 12V with a tolerance range of ±2V. Do not apply more than 14V to the power input of the MCA, otherwise the device may be destroyed.

Also, do not apply any voltage to the wall plug adapter which is outside its input range. Usually this is 100VAC...240VAC. Never use a damaged wall adapter!

2.1.2 High Voltage Supply

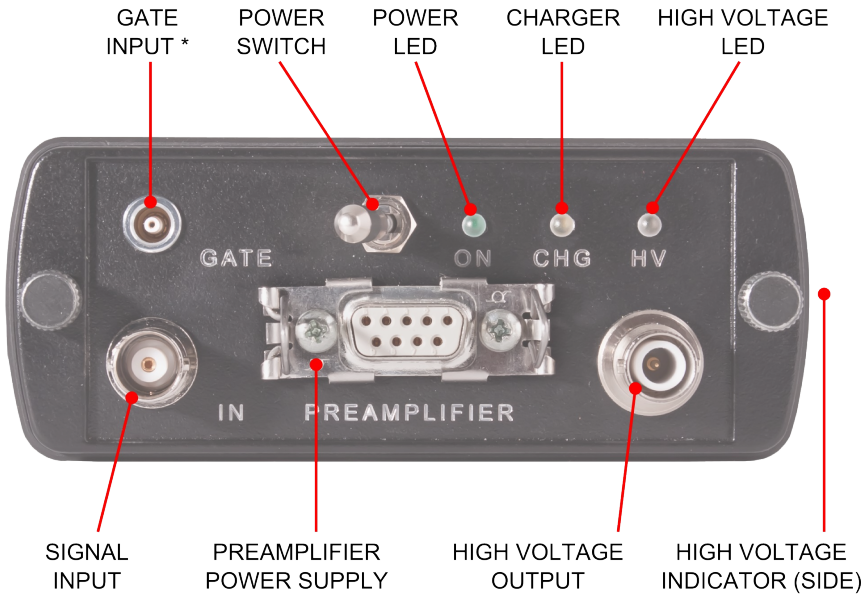
Make sure that the high voltage connector and the high voltage supply cable of the detector are in a good condition before connecting them to the MCA527 or before switching the high voltage on. Do not allow anything to rest on the HV cable.

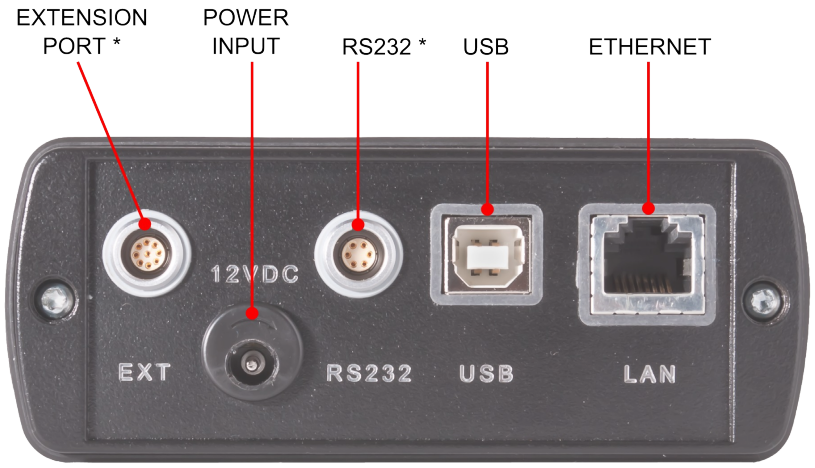
Never insert objects of any kind into the high voltage connector as they may touch the dangerous voltage point. This might cause an electric shock or a damage of the device.

2.2 General Hardware Description

The MCA527 is an autonomous module. The device has its own battery and provides power supply to radiation detectors. Together with a computer and a detector the MCA527 forms a gamma spectroscopy system. The spectra are collected in the memory of the MCA527 and periodically transferred via a communication interface to the computer. The computer is used to setup the MCA527, to display and process the measurement results, and to store the data. The design concept of the MCA527 also supports a multi-channel scaler mode.

For operation the MCA527 itself has only a power switch and three LED indicators on the front panel. Figure 1 shows the MCA527 front and rear panel with all connectors, control elements and indicators.





* not available in Lite-version

Figure 1: MCA527 connectors and control elements

2.2.1 Switching on the Device

The MCA527 is set into operation by turning on the power switch (Figure 1). After that the power supply checks the battery voltage and if it is higher than 6.8V it supplies the complete device with power. The main processor boots now and the three LED indicators flashes some times alternately for about 3 seconds. After finishing the boot process the device enters into the idle state and the green LED flashes symmetrically with 2.5Hz. When a connection to a control program was established the device enters into the normal state and the green LED flashes symmetrically with 1.25Hz.

When the MCA527 is not working but the main switch is still on, the device has turned off automatically because of a power failure or a loss of battery power. If a power failure occurred, turn off and on again the main switch. The device should reboot and enter into the idle state. If the batteries are empty, connect a charger first. The yellow LED shines during charging and when the battery voltage reaches 6.8V the MCA527 turns on automatically.

2.2.2 LED Indicators

The LEDs indicates the actual device state even if no computer is available or located far away from the MCA. All possible states are shown in Figure 2.

The green LED shows the device state. After turning on, the device enters into the idle state and only the green LED blinks symmetrically with 2.5Hz. When a successful communication takes place, the MCA enters into the normal state and the green LED blinks with 1.25Hz until a failure occurs. The failure is displayed by asymmetric blinking of the green LED. During a firmware update the green LED shines permanently.

When the yellow LED shines it indicates that the internal charger is powered from an external source (wall adapter or USB port) and charges the batteries. This LED shines even if the MCA is turned off and the batteries are charged.

A red/blue bi-color LED displays information about the high voltage. If the LED is dark, the HV is turned off. When it flashes red or blue with app. 1Hz the high voltage is active and works properly. During the change from one value to another, the HV-LED is permanently on until the high voltage has reached the new value. If a high voltage failure occurs, this LED blinks red and blue alternately.

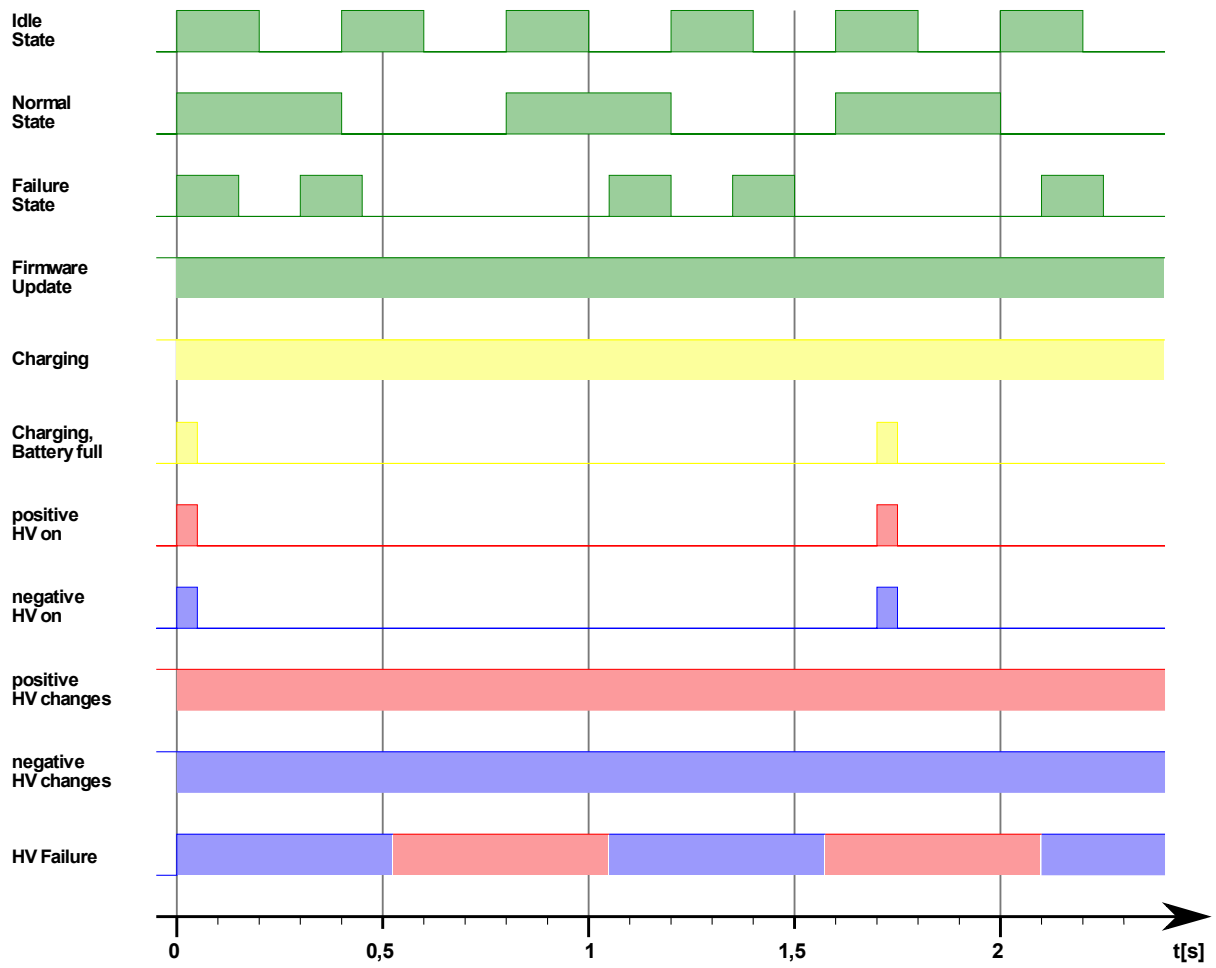


Figure 2: LED Indicator blinking scheme

2.2.3 Power Management

The MCA527 works with a built in rechargeable Li-Ion battery, which has no memory effect and is deep discharge and short circuit protected. If the device is working, the remaining battery life time is permanently checked. When the battery voltage has dropped down to 6.8V while a data collection is in progress, the MCA527 gives out a warning to the user (the lamp will flash irregularly and the software will show an error message). The running measurement is automatically stopped and the detector high voltage together with the preamplifier power supply will be switched off.

Now the user can transfer the measured spectrum to the computer, but should switch the device off afterwards or connect an external power source (wall adapter). If the user does not respond, and the battery life time is nearly used up (battery voltage 6.5V) , the device switches off automatically. It is made sure, that the setup and the spectrum gathered previously is saved in the memory of the MCA527 permanently.

The remaining battery life time is sufficient to transfer the measured spectrum to a computer. It is recommended, before reading out the MCA527, to connect it to an external power source.

In the case that the battery voltage drops below its lowest value, the battery itself switches off. This can be, for example, the result of a lasting short circuit at the preamplifier power supply. As a consequence the internal setup and the measured values are lost. The MCA527 has to be connected to an external charger to recharge the battery.

2.2.4 Charging the MCA527

Charging the MCA battery is usually done by connecting the wall adapter to the power input connector and power it from the mains supply. The wall adapter is able to deliver enough power to operate the MCA527 stationary under a maximum load condition (HV on, detector draws up to 2W preamplifier power). If the MCA527 is operated on a high power USB hub and the wall adapter isn't connected, it can be charged from the USB port. But there is a limitation of 2,5W nominal input power which is the maximum power that can be drawn from a high power USB port (real usable input power depends on hub voltage, voltage loss on USB cable and connectors and efficiency of internal charger; it is usually about 2W). This is enough power to operate the MCA527 without detector or with a low power detector (e. g. CdZnTe or NaI). If a detector draws to much power from the MCA527 (e. g. some HPGe), charging via USB is still working but the battery runs out slowly.

There are two different variants of behavior when the MCA527 is connected to a working high power USB hub. Each variant has advantages and disadvantages. The variant is hard coded within the MCA527.

Variant 1: Charging keeps switched off when the MCA527 is connected to a working high power USB hub. This saves the laptop battery from potential discharge, however, the MCA battery will be potentially emptied.

Variant 2: Charging is started after 6 seconds automatically when the MCA527 is connected to a working high power USB hub. This saves the MCA battery from potential discharge, however, the laptop battery will be potentially emptied. One advantage of this variant is that a MCA527 that battery is fully discharged can be operated without a wall adapter.

Since the most users prefer the first variant, it is the standard variant. It is however possible to get the second variant on request.

It is possible to enable or disable USB charging by newer application programs such as WinSPEC. Connecting the wall adapter to the MCA527 and supply it with power will always turn off USB charging.

The old battery chargers supplied with the MCA166 (3 pin LEMO connector) or the MCA166-USB (2 pin LEMO connector) are not compatible with the MCA527! Don't try to connect them to the MCA527. The connectors are mechanically different.

With the MCA527 it is possible to use a cheap wall plug supply in emergency cases. However this is not recommended, as cheap supplies have no locking connector, can make problems with electromagnetic compatibility, there may be supplies with compatible plug but unsuitable voltage, and even unregulated nominal 12V supplies may have idle voltages as high as 20V which may destroy the MCA527. So when using an alien power supply make at least sure that the inner connector is positive and the idle voltage is not higher than 14V.

2.2.5 Exchanging Batteries

The rechargeable batteries of the MCA527 are long lived Li-Ion batteries of the type Sony NP-F570 or comparable. If however it is necessary to exchange the batteries, it is as simple as exchanging the HV module. Proceed as follows:

- Switch off MCA
- Remove both screws on the front panel.
- Pull off the front panel. Attached to this is the base board with the HV module and the batteries. Pull it fully apart.
- Remove old batteries. Just pull them off to the side.
- Make sure that the new batteries have exactly the same voltage / charge state. The voltage difference must never exceed 0.5V, otherwise there is the danger of battery destruction.
- It is also possible to operate the MCA with only one battery inserted, but then operation time is reduced to 40%...50%. The MCA527L comes with only one battery inserted.
- Afterwards insert the base board in the correct slit, and also be careful with inserting the upper board plug.
- Make sure that the rubber is correctly between housing and front panel and fasten screws.

2.2.6 Connecting the MCA527 to a Computer

Three different communication interfaces are offered by the MCA527. Depending on the situation each interface has various advantages.

The standard RS232 interface is available via a 6 pole Lemo socket. Because this is the same like on the MCA166-USB, the RS232 cable from the MCA166-USB can be used. Three different baud rates are supported by the MCA527, 38.400, 115.200 and 307.200 Baud. All newer application programs for the MCA are using always the highest possible baud rate depending on the computer hardware. Because the firmware of the MCA527 is able to detect the hosts baud rate automatically, usually no manual interface configuration is necessary.

If the host computer offers an USB host controller, communication can be done via the USB interface. Independent of the application program and the host computer hardware the used baud rate is always 3MBaud. This is nearly ten times faster than the highest possible RS232 baud rate. Another advantage of the USB interface is the possibility to charge the MCA527 from the USB port. USB charging is only possible if the MCA is connected to a high power USB hub (see also 2.2.4 Charging the MCA527).

The MCA527 has got an Ethernet interface that supports 10/100MBit/s. By default it is configured to obtain the IP address automatically from a DHCP server or if not available, to use Zero Configuration Networking (also named Automatic Private IP Addressing), but it is also possible to set a fixed customized IP address. For that a special program is required.

Running the MCA527 on a Palmtop computer or Pocket PC is possible in most cases but needs a special communication cable. Please contact GBS-Elektronik (http://www.gbs-elektronik.de) for availability. For proper wiring see Figure 27: MCA527 Block Diagram on Page 63.

2.2.7 Connecting Detectors

Before connecting a detector **switch off the device** and make sure that the built in high voltage power supply has the **correct polarity** and that the power consumption of the detector does not **exceed the maximum ratings of the high voltage power supply module (0.5mA or 0.25 Watt).**

Checking the high voltage modules polarity is simply possible by viewing inside the MCA through the small whole on the right side of the MCA527 (see Figure 1). If it shines red a positive HV module is inserted, if it shines blue a negative HV module is present. If the indicator is black / dark gray no HV module is present. Furthermore it is possible to check the HV polarity by software; go to the menu *setup / high voltage*[2] and look for the HV polarity. The correct values for HV, polarity, and power consumption should be found in the detectors manual.

- Check the detector manual for MCA527 compatible pin assignment of the preamplifier power supply connector and that the power consumption does not exceed the maximum ratings (see chapter 8.1.2).
- Connect the detectors preamplifier power supply cable to the corresponding female D-SUB9 socket on the MCA527 and attach it by the clamps.
- Connect the detectors BNC Signal cable to the MCA's BNC input connector.
- Connect the detectors high voltage cable to the MCA's SHV connector.

If problems occur, it is possible to check the detector signal with a scope or in the scope mode of WinSPEC-A. A typical signal which should be seen is shown in Figures 3 and 26.

2 available in most application programs, e. g. WinSPEC and WinSCAN

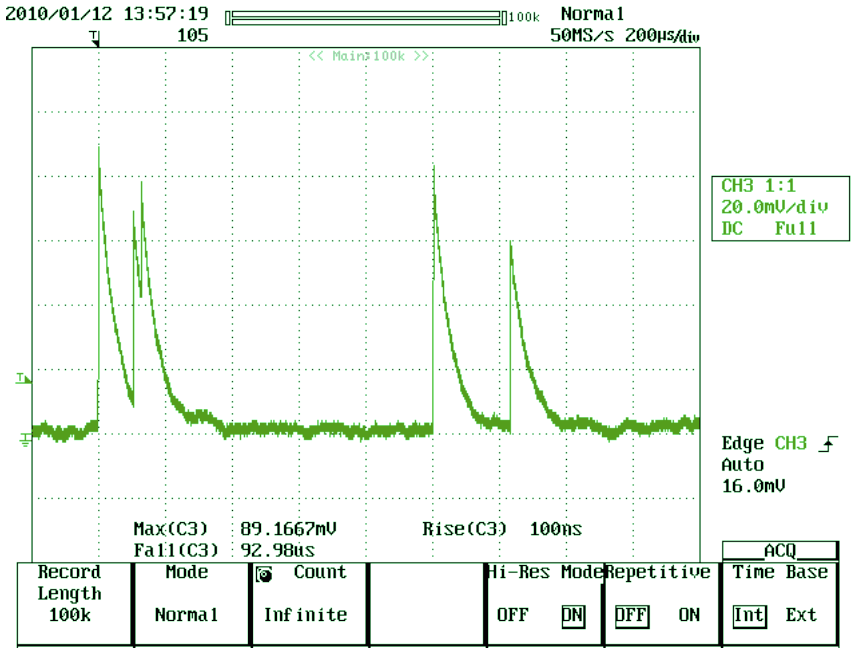


Figure 3: Typical signal which can be seen at a detector preamplifier output, here from a CZT500 detector. For optimum performance, the rise time should be in the order of 100ns, and decay time constant of 50µs. This is drop to 36.8% of peak value within 50µs or drop to half value within 34.6µs.

2.2.8 Applying High Voltage

Most gamma detectors require some high voltage (HV) supply. The MCA527 is able to provide this. However, mistakes with the high voltage can seriously damage detectors, therefore some caution is recommended.

- Before applying HV make sure that detector is properly connected.
- Check that the polarity of HV module inserted is correct for connected detector.
- Do apply the correct voltage for the detector.
- Do not plug or unplug HV cables while HV is on.
- In case of a HPGe detector, make sure that the detector is fully cooled down for a few hours.

There are also some specific properties for different detector families which are discussed below.

Scintillation Detectors as NaI, LaBr, etc.

For scintillation detectors, the HV is needed for the operation of the photomultiplier. The photomultiplier acts as some kind of amplifier whose amplification is strongly dependent on the high voltage setting. Therefore, it is necessary that this voltage is very stable. However, here the HV can also be used to adjust the gain and optimize performance. A rule of thumb is that the preamplifier output signals should be in the order of 0.5V…1V. If HV is too high, non-linearities of the photomultiplier may become significant in the spectrum, whereas with too low HV signals become small and noise may become significant and degrade the resolution. Scintillation detector manufacturers tend to give slightly higher than optimum values for high voltage in their data sheets.

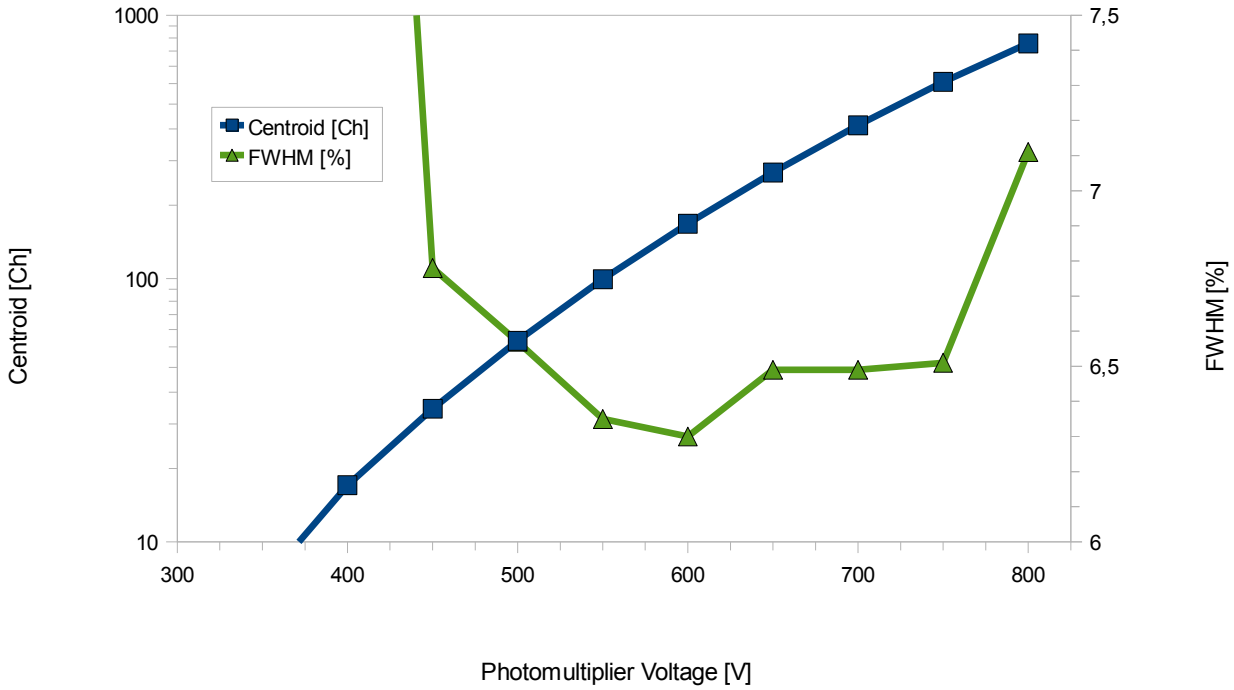


Figure 4: Dependence of peak position and resolution on high voltage, using a NaI detector

High Purity Germanium (HPGe) Detectors

A HPGe detector is basically a huge cooled high voltage germanium diode with a big radiation sensitive depletion region. In first order, the output does not depend on HV setting as long as the voltage is above a certain voltage and the detector is fully depleted. Below that value, the resolution degrades, the sensitivity decreases and the signals get smaller.

This is important when dealing with detectors whose HV rating (e. g. 4500V) is above the 3600V the MCA527 can supply[3]. If the 3600V is still above the depletion point, it is no problem to use this detector with lower voltage. However, it is not possible to estimate the depletion voltage from the detector nominal voltage; this has to be found out experimentally.

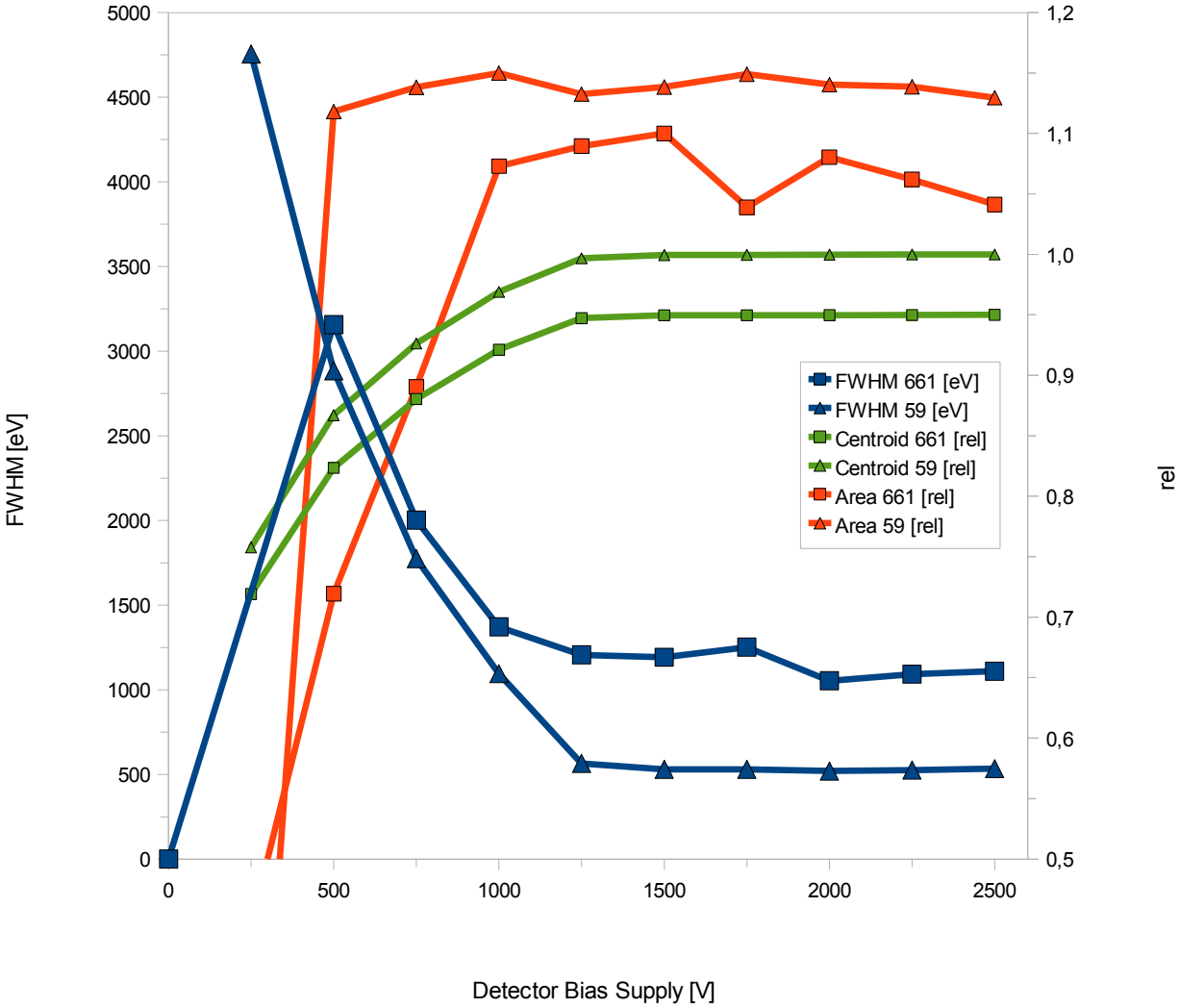


Figure 5: Typical dependence of FWHM, Centroid position and counting rate on HV setting. Peaks at 59 keV and 661 keV are used for evaluation. The nominal rating of this detector is 2500V, the depletion point is at 1250V.

3 In conjunction with a HV3600 high voltage module

Most important when applying HV to a HPGe is that the detector must be cooled down properly and must not become warm while HV is on. As this is a mistake which easily destroys expensive HPGe detectors, most HPGe have a HV inhibit out which becomes active if the detector gets warm. The HV inhibit input for the MCA527 is Pin 5 of the D-SUB9 preamplifier power connector (see chapter 2.2.12, Preamplifier Power Supply Connector). As some HPGe have the HV inhibit out on a separate BNC cable, a corresponding adapter is optionally available.

Table 1: HV-Inhibit Signal

HV-Inhibit mode[4]	Detector inhibit output voltage, inhibit active	Inhibit voltage, detector cold	MCA527 condition to switch HV off
off			-
BSI, DFG, Canberra	0V	+12V	$V_{PIN5} < 0.5V$
Ortec	+5V	0V	$V_{PIN5} > 0.5V$

The voltage with connector open at the HV inhibit input of MCA527 is around 2.2V. So for HV inhibit to work properly with Canberra detectors, it must be made sure that the inhibit is really connected. For Ortec detectors, unconnected HV is similar to detector warm, so there is no problem. This behavior is opposite to MCA166, which interprets open input as 0V.

Room Temperature Semiconductor Detectors

Room temperature semiconductor detectors (CZT) behave somehow similar to HPGe, Centroid position depends rather weak on HV setting. Choosing a too low voltage effects that charge loss processes become more dominant and therefore the peaks more asymmetric. With a too high voltage, leakage currents become a problem which cause additional noise and therefore peak broadening. Best is to stay with the rated voltage.

2.2.9 Exchanging the High Voltage Module

Switching from positive HV to negative HV can only be done manually by exchanging the HV module. Proceed similar as described in chapter 2.2.5 Exchanging Batteries. When inserting the HV module be careful to insert all pins properly and not to bend or break off pins.

2.2.10 Functions of the D-SUB9 connector

Different functions are available on the MCA527 D-SUB9 connector which are useful with various detectors. Figure 6 shows the block diagram. The MCA527OEM has not implemented this functions and the MCA527L only supports the ±12V supply. The pin diagram of the D-SUB9 connector is shown in Table 3.

Traditionally this port is used to provide the supply voltages for the detectors preamplifier. The MCA527 delivers ±12V and ±24V while the MCA527L delivers only ±12V. Each voltage can be loaded with up to 60mA. Furthermore the MCA527 has some additional features. Some HPGe detectors provides a HV inhibit signal which indicates that the

4 see Windows DLL description

detector gets warm an the HV must be turned off. The MCA527 is able to interpret this signal for different detectors if it is routed to pin 5 of the D-SUB9 connector. A BNC adapter is available from GBS-Elektronik GmbH. For more information see chapter 2.2.8, Applying High Voltage.

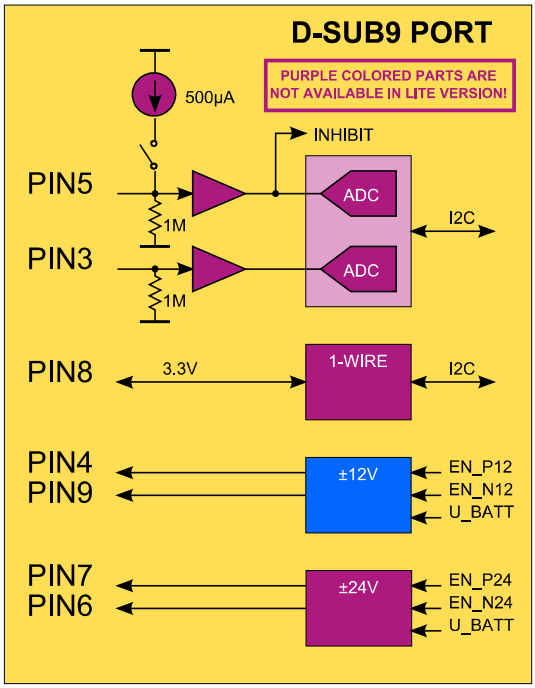


Figure 6: Block diagram of all components connected to the D-SUB9 connector. Only the MCA527 supports all functions, the MCA527L is only populated with the ±12V preamplifier power supply.

Some NaI-detectors are equipped with a 1-wire temperature sensor. If the sensors is connected to pin 8 of the D-SUB9 connector, the MCA527 is able to read out the detectors temperature and displays it in the diagnostics menu. Currently only the DS1822 sensor is supported by the firmware but in principle every 1-wire device which operates at 3.3V can be used on the MCA527.

Other NaI-detectors have an integrated thermistor for measuring the crystals temperature. The resistance of this sensor can be measured with the MCA527 on Pin 5 of the D-SUB9 connector. By turning on the internal current source a constant current of about 500µA is fed into the thermistor and the resulting voltage is measured with the ADC on pin 5 (see Figure 6). The application program calculates the corresponding resistance and temperature with respect to the input impedance and displays it in the diagnostics menu. Because the current source has a relative large tolerance, its real value is measured during production and stored inside the MCA. This parameter is used for calculating the resistance. Resistors up to 8kΩ can be measured.

If the current source is turned off, pin 5 of the D-SUB9 connector can be used as general purpose analog input like pin 3 too. Both inputs accepts voltages between 0V an 10V and are sampled nearly every second with a resolution of 11bit. The voltages are displayed in the diagnostics menu.

2.2.11 Extension Port

The extension port is only available on the MCA527, the MCA527L and the MCA527OEM are not equipped with this functionality. This port extends the possibilities of the MCA enormously. Different external devices, such as GPS receivers or neutron counters, can be attached to the MCA527 by a 9 pin Lemo connector (Table 6). Figure 7 shows the block diagram. Currently the basic functionality is implemented in the firmware but no application program takes advantage of it.

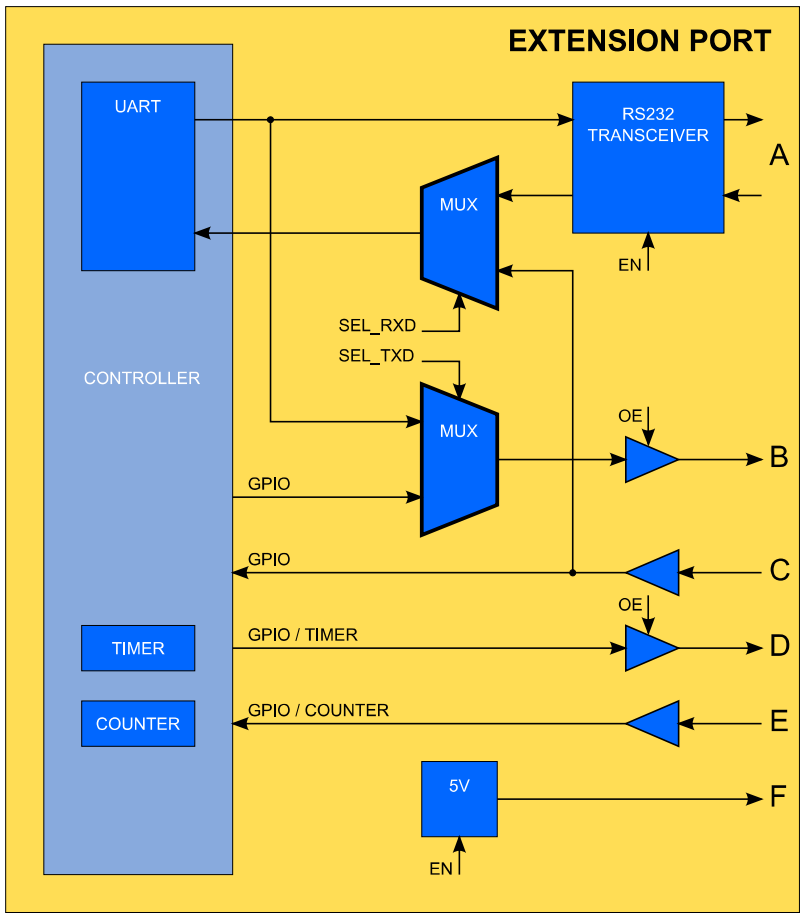


Figure 7: Block diagram of the extension port. This functions are only supported by the MCA527.

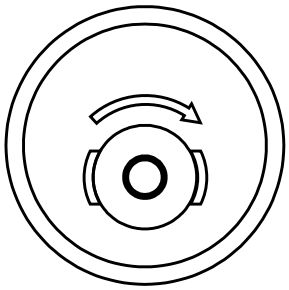
The extension port consist of six independent parts labeled A to F. Part A is a true RS232 interface which can operate at speeds up to 1MBaud. To save power, the transceiver is disabled by default. Part B is a 3.3V digital output with output enable. It can be used as general purpose output or as TTL-UART TxD. Part C is a 3.3V digital input which is 5V tolerant. It can be used as general purpose input or as TTL-UART RxD. The TTL-UART can be operated at speeds up to 3MBaud. Part D is an additional 3.3V digital output with output enable. It can be used as general purpose output or as timer output for pulse generation. Part E is a further 5V tolerant 3.3V digital input which can be used as general purpose input or as fast counter. To supply external devices with power, a 5V converter is also part of the extension port (F). It can be loaded with up to 100mA. To save power, it is disabled by default.

2.2.12 Connector Pinouts

Charger Connector

The charger connector is a widespread low voltage connector, but allows to lock the plug. The inner diameter is 2.1mm, the outer diameter is 5.5mm.

Table 2: Pinout of the Charger Input Connector (Lumberg 161003)

Contact	Signal	Front View
1 (inner contact)	+12VDC / 1A max.	
2 (outer contact)	0V	

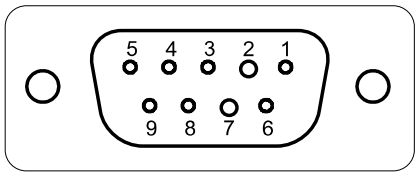
Preamplifier Power Supply Connector

Besides supplying power for the detectors preamplifier, three pins of this connector have special functions which are only available in the MCA527 and not in the MCA527L.

- Pin 5 is a multi-function input. It can operate as a HV-inhibit input to shut down high voltage in case a HPGe gets warm. If this function is not needed, it can be used as an auxiliary analog input with 0V...10V input voltage range and 11bit resolution. In conjunction with the calibrated built-in current source it is well suited for measuring external resistors in the range of 0Ω...8kΩ. This feature allows easy analyzing of a thermistor or any other resistive sensor.
- Pin 8 serves a 1-wire interface designed to communicate with a temperature sensor inside the detector (e. g. Maxim DS1822, 18B20 or similar) or any other 1-wire device. The bus is powered with a voltage of 3.3V. All externally connected devices must be able to accept this voltage. Currently only the DS1822 (or compatible) temperature sensor is supported but functionality may be extended on request.
- Pin 3 is an auxiliary 11bit ADC input with an input range of 0V...10V and an input impedance of 1MΩ which is sampled once a second. It is integrated for future extensions, e. g. measuring temperature with an analog temperature sensor or similar.

A block diagram and a more detailed description of all functions can be found in chapter 2.2.10, Functions of the D-SUB9 connector.

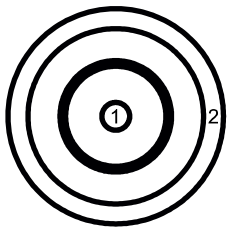
Table 3: Pinout of the Preamplifier Power Supply Connector (D-SUB9 female)

Contact	Signal	Front View
1	GND	
2	GND	
3	auxiliary analog input 1[5]	
4	+12V / 60mA max.	
5	HV-Inhibit input[5] / auxiliary analog input 2[5] / thermistor input for NaI detectors[5]	
6	-24V / 60mA max.[5]	
7	+24V / 60mA max.[5]	
8	1-wire interface (In / Out)[5]	
9	-12V / 60mA max.	
shield	GND	

Gating Input

The gating input can be used to blank out specific pulses (e. g. LED-pulses from a LED-stabilized NaI detector). It accepts 3.3V TTL pulses but is also 5V tolerant. This connector is only available in the MCA527 and not in the MCA527L.

Table 4: Pinout of the Gating Input Connector (Lemo ERA.00.250.NTL)

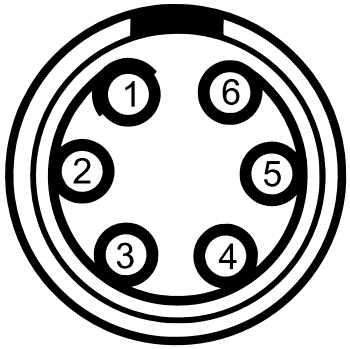
Contact	Signal	Front View
1 (inner contact)	gate input (TTL, 5V tolerant)	
2 (outer contact)	GND	

RS232 Interface Connector

The RS232 connector is a 6-pin Lemo connector, the same as used with MCA166-USB. This connector is only available in the MCA527 and not in the MCA527L.

5 Only available in MCA527 and not in MCA527L

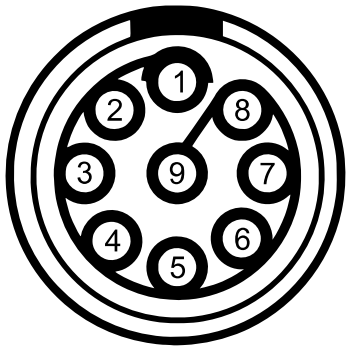
Table 5: Pinout of the RS232 Interface Connector (Lemo EGG.0B.306)

Contact	Signal	Front View
1	not connected	
2	not connected	
3	not connected	
4	GND	
5	RxD (input)	
6	TxD (output)	

Extension Port Connector

The extension port is for future extensions, e. g. connecting a GPS receiver. Other applications are integrated on request. This connector is only available in the MCA527 and not in the MCA527L.

Table 6: Pinout of the Extension Port Connector (Lemo EGG.0B.309)

Contact	Signal	Front View
1	RxD_{ext} (RS232, input)	
2	TxD_{ext} (RS232, output)	
3	shield	
4	$O1_{ext}$ / TxD_{extTTL} (output)	
5	$I1_{ext}$ / RxD_{extTTL} (input)	
6	$I2_{ext}$ (input)	
7	$O2_{ext}$ (output)	
8	$5V_{ext}$ (100mA power output)	
9	GND_{ext}	

2.2.13 Accessories

The following items are either shipped with the MCA527 or are optional available.

Table 7: MCA527 Accessories

Item	Description	Included
HV module +3600V	for supplying detectors with positive high voltage	MCA527
HV module -3600V	for supplying detectors with negative high voltage	MCA527
HV module +1000V	for supplying detectors with positive high voltage	
HV module -1000V	for supplying detectors with negative high voltage	
Charger MCA527	For charging and stationary supply of the MCA	MCA527
Cable MCA-PC, RS232	For connecting the MCA527 to a Computer with RS232 interface. Same cable as for MCA166-USB	MCA527
Cable MCA-PC, USB	For connecting the MCA527 to a Computer with USB port.	MCA527, MCA527L
Cable MCA-Pocket PC, RS232	For connecting the MCA527 to a Pocket PC with RS232 interface and special connector.	on request
Cable MCA-PC, Ethernet	For connecting the MCA to a local area network or directly by Ethernet to a computer.	MCA527, MCA527L
Adapter for HV inhibit signal	Connects the inhibit signal from a HPGe detector, which is on a BNC cable, to Pin 5 of the D-SUB9 connector of the MCA527.	MCA527
Adapter cable lemo-BNC	Allows to connect a BNC cable to the gate input of the MCA527	on request
Li-Ion batteries	rechargeable, inside MCA, only to be exchanged when defective.	2pc with MCA527, 1pc with MCA527L
shipping box	convenient suitcase to carry MCA, accessories, and smaller detectors.	MCA527
Software CD	Includes all software also available on GBS Elektronik web site, manual.	MCA527, MCA527L.

2.3 MCA527OEM Specific Items

The MCA527OEM is a PCB-only version of the MCA527 which is hardware- and software-compatible to the MCA527 but not identical. It is intended for customers who wants to integrate a MCA into their own devices or systems. Figure 8 shows the board. The size is 134mm x 60mm without USB- and Ethernet connector. The four mounting holes are 3.2mm in diameter and located 3.0mm away from each board edge. The MCA527OEM is available as Ethernet version without USB interface or as USB version without Ethernet interface. RS232 interface is possible on request.

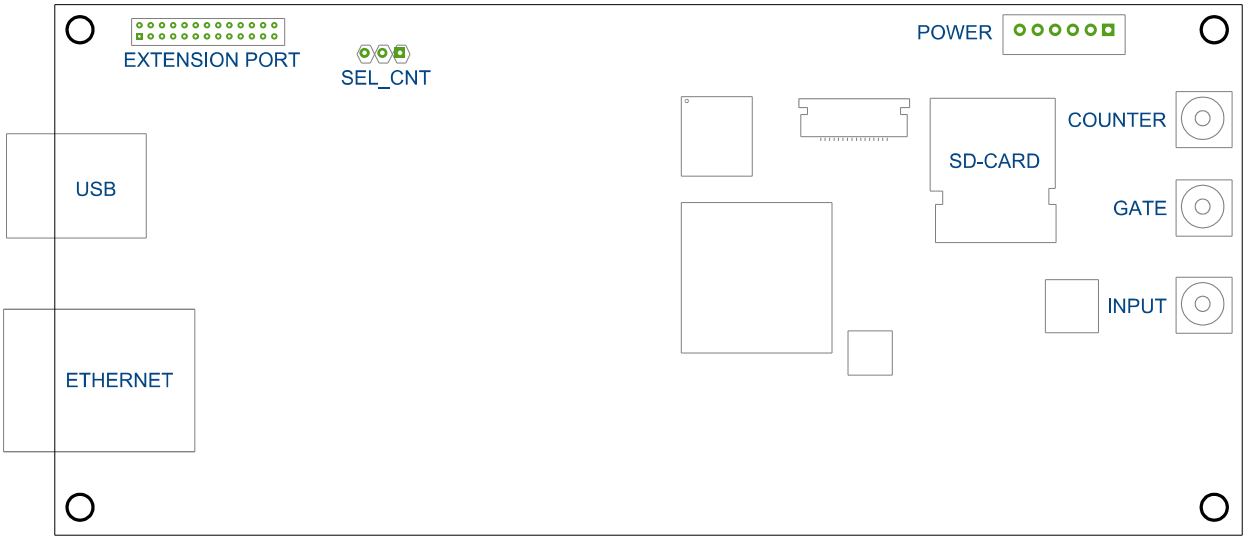


Figure 8: MCA527OEM printed circuit board

The board is powered through the 6 pin power connector (Table 8). The Ethernet version works with voltages between 3.3V and 9V while the USB version needs an input voltage of 4.5V to 9V. Powering the MCA527OEM through the USB port is not possible. MCX coaxial connectors (Telegärtner J01271A0131, series J0127) are used for the signal input, the gate input and the counter input. Corresponding plugs, such as the J01270A0161, should be used for connecting these signals to the MCA527OEM. It is possible to equip the MCA527OEM with the extension port like the standard MCA527. However, this port is prepared but not available in the standard version of the MCA527OEM and will be realized on request only! The extension port signals would be available on the OEM extension port connector (Table 9). The Jumper SEL_CNT selects the counter input. It must be in the 1-2 position if the MCX coaxial connector should be used as counter input. If it is in the 2-3 position, pin 25 of the OEM extension port connector must be used as counter input.

Table 8: Pinout of the Power Connector (JST B6B-PH-K-S)

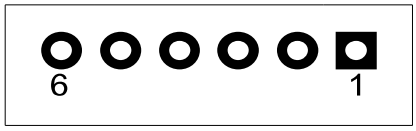
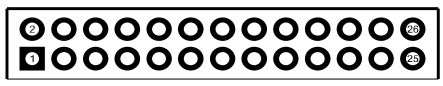
Contact	Signal	Top View
1	V_{in} input voltage (3.3V...9V)[6]	
2	GND	
3	GND	
4	V_{RTC}[7] 3.3V power supply for real time clock	
5	SDA[7] I^2C-interface data line	
6	SCL[7] I^2C-interface clock line	

Table 9: Pinout of the OEM Extension Connector (Male Header 2 x 13, Pitch 1.27mm)

Contact	Signal	Top View
1	shield extension port	
2	shield RS232 interface	
3	RxD_{ext} RS232 extension port	
4	RxD RS232 interface	
5	GND_{ext} extension port	
6	GND RS232 interface	
7	TxD_{ext} RS232 extension port	
8	TxD RS232 interface	
9, 10, 13, 15	not connected	
11, 12, 17, 18, 23, 24	GND	
14	SDA I^2C-interface data line	
16	SCL I^2C-interface clock line	
19	$O1_{ext}$ / TxD_{extTTL} (output)	
20	3.3V / 100mA power output	
21	$I1_{ext}$ / RxD_{extTTL} (input)	
22	$O2_{ext}$ (output)	
25	$I2_{ext}$ (input)	
26	$5V_{ext}$ / 100mA power output	

6 USB version works only with voltages between 4.5V and 9V.
7 V_{RTC}, SDA and SCL are currently not present at this connector.

3 Pulse Height Spectroscopical Measurements

3.1 Introduction to Digital Signal Processing

The main task of a multi-channel analyzer is to measure the height of voltage steps. In a conventional analog MCA the voltage step is converted by a Gaussian bandpass filter into a pulse with several microseconds pulse width, a peak detector converts this to a DC voltage, which is then measured with a single conversion of an analog to digital converter (ADC). Typical there is also a fast channel, which converts the signal to very narrow pulses for counting, triggering, and rejecting events which are in too short time distance to be measured correctly (Pile up rejection, PUR).

In a digital MCA the input signal is digitized with a high rate, and the amplitude is calculated from a multitude of measurements. The MCA527 samples the input signal with a 14 bit ADC and a rate of 10MS/s, this is one voltage measurement every 100ns.

Digital filtering with a finite impulse response (FIR) filter is now just multiplying the incoming train of measurement values with a fixed row of numbers and adding up all the results. This row of numbers is the digital filter. A signal processor is especially designed to perform such a task.

Also with a digital MCA the signal processing is split up into a fast and a spectroscopical (slow) channel. A short trigger filter is applied to the incoming signal every 100ns, whereas the long spectroscopical filter is only applied if a valid event was found.

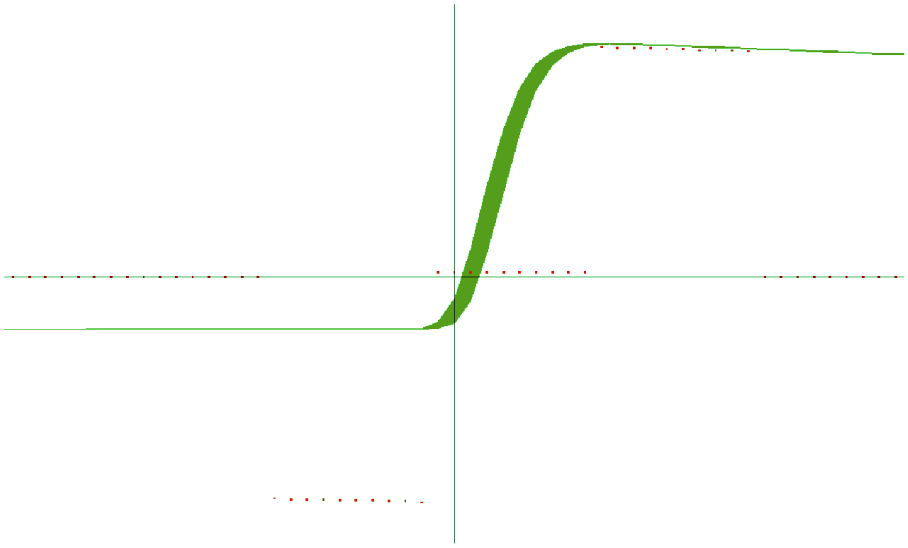


*Figure 9: Example of a digital filter applied to a voltage step. Here the flattop time is 1µs (10*100ns) and the shaping time 0.5µs (≙1µs rise time)*

The simplest method to measure the step voltage is to take one value before the step and one after the step and subtract them from each other. This would correspond to a digital filter looking like -1, 0, 0, 0, 0, 0, 0, 0, 0, 1. But such a filter would be quite unusual as the accuracy of this would be rather bad compared to what is obtainable.

The main errors of an ADC are amplitude noise and timing error. So for minimizing the errors, it is advisable to use more than one voltage value before and after the step for averaging, and to avoid using voltage values where the voltage is changing quickly. So typically between 10 and 100 values before and after the rise are averaged. This time

over which the values are averaged is often found as rise time. This rise time is in effect comparable to the shaping time of an analog shaping amplifier, and comparable results are achieved if the rise time is twice the shaping time. For compatibility reasons, the MCA527 uses still the term “shaping time” and the rise time is just twice as high as that.

Further the values near the voltage step are omitted from calculation. This parameter is called flattop. The above mentioned very simple filter would have a flattop of 0.8µs and a shaping time of 0.05µs.

But there are more things to optimize a digital filter for and to be taken into account:

- A voltage step sitting on top of a previous step should be calculated to the same amplitude as if it was starting from the baseline. This correction is adjusted with the pole zero setting.
- The positioning of the filter has typically an accuracy not better than the sample rate, here 100ns. So the filter should be adjusted such that the result is invariant to a shift of 100ns forward or backward. This correction is also derivated from the pole zero setting.

3.2 Adjustments and Settings

3.2.1 Input Polarity

Has to be chosen whether the detector preamplifier delivers positive voltage steps or negative.

3.2.2 Coarse Gain

Can be adjusted between 2 and 1000, but only settings between 2 and 100 affect the signal input amplifier / attenuator. It defines which signals can be processed.

Table 10: Input signal acceptance range depending on coarse gain

Coarse Gain	Full Input Range	Useable Input Range Positive Polarity	Useable Input Range Negative Polarity
2	12.50V	-1.25V...11.25V	-11.25V…1.25V
5	5.00V	-0.5V...4.5V	-4.5V…0.5V
10	2.50V	-0.25V...2.25V	-2.25V…0.25V
20	1.25V	-125mV...1125mV	-1125mV…125mV
50	0.50V	-50mV...450mV	-450mV…50mV
100	0.25V	-25mV...225mV	-225mV…-25mV

For best resolution, the coarse gain setting should be chosen as high as possible but still fits into the input acceptance range. However, above a coarse gain of 20 the improvements are marginal, and coarse gain settings above 100 have been omitted as there is no benefit for this and are just calculated.

3.2.3 Fine Gain

The fine gain is to fine adjust the gain and therefore the energy to channel ratio. This gain is just a mathematical factor used for calculation of the filter. The highest dynamic range (ratio of low energy cutoff to maximum energy in spectrum) and best resolution can be achieved when using a rather high coarse gain and a low (e. g. 0.5) fine gain. With higher count rates (>10kcps) it is however recommended to stay with fine gain above 1 and to reduce coarse gain.

The adjustment range is 0.5 to 6.5, default is 1. This adjustment range was chosen to be compatible to MCA166 which has a range of 0.5 to 1.5, and to extend it also to larger values which is useful for real high count rates.

3.2.4 Trigger Filter

The trigger filter is applied continuously to the incoming signal to check for events (voltage steps). Also here are selections possible which represent trade off between time resolution and sensitivity. The simplest trigger filter is the -1, 1 filter which just checks the difference between subsequent incoming values and therefore performs a single differentiation. Even more sensitive is the -1, 0, 1 filter which checks the difference between incoming signals of 200ns distance.

The best pulse pair resolution (ability to distinguish between close following events) is however achieved with a double differentiating filter as the 1, -2, 1. But double differentiating increases the noise level and therefore this filter is not as sensitive. A compromise is the 1, 0, -2, 0, 1 trigger filter, which has still a good time resolution but a better sensitivity then the 1, -2, 1.

*Table 11: Properties of different trigger filters. Dynamic range tested with GL2010R, amplification 5*0.5, 4096 channels, shaping time 2µs flat 0.8µs*

Trigger Filter	Pulse Pair Resolution	Best Dynamic Range Possible	Lower Energy Cutoff in % of Full Scale
-1, 0, 1	860ns	1:625	0.16%
-1, 1	760ns	1:353	0.28%
1, 0, -2, 0, 1	330ns	1:325	0.30%
1, -2, 1	240ns	1:169	0.60%

Default is the 1, 0, -2, 0, 1 filter as a good compromise for both sensitivity and time resolution. In case of a low count rate (<5kcps) and a required high dynamic range (low energy part of the spectrum also important) the filter -1, 0, 1 is recommended. The 1, -2, 1 is best at high count rates and where the lower end of the spectrum is not really important. The -1, 1 is more a bad compromise and just here because it is the shortest and needs the least processor power.

For best pulse pair resolution, the preamplifier signal should be steep, but it should not exhibit any ringing. In case of ringing or overshoot, the trigger filter will trigger multiple times on a single signal and therefore consider this erratically as pile up. A preamplifier ringing or overshoot problem can be suspected if dead time is much higher than expected. In such a case try a single differentiating trigger filter such as -1, 0, 1 or -1, 1. If this does not help, switch pile up rejection off.

The MCA527L only supports the 1, 0, -2, 0, 1 trigger filter.

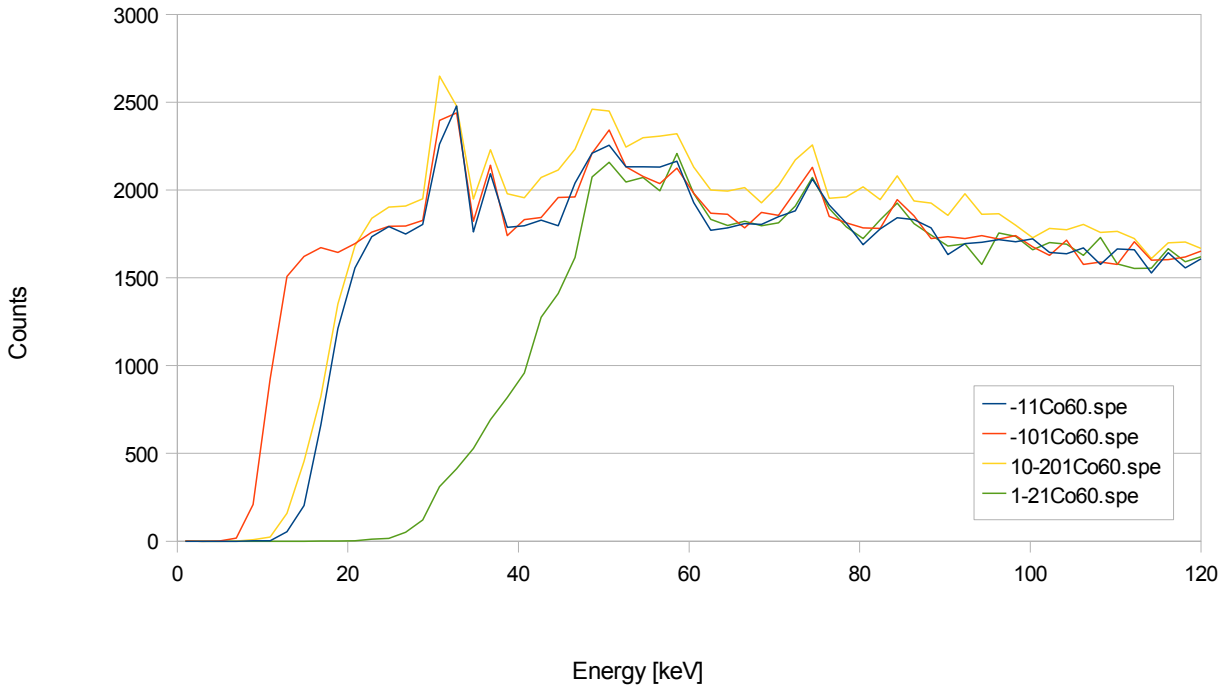


Figure 10: Low end spectrum cutoff depending on trigger filter. Spectrum range in all cases is 8MeV, whereas the 1, -2, 1 cuts off the spectrum already at a quite high energy of 48keV, the -1, 1 and the 1, 0, -2, 0, 1 go down to 23keV, and the -1, 0, 1 allows still energies down to 13keV to be seen.

3.2.5 Trigger Level

The trigger level is normally automatically adjusted to 7 times the evaluated RMS noise level by default. This works fine for almost all tasks. However, a detector may exhibit non Gaussian noise or there may be other high frequency disturbances around and therefore a reason to readjust trigger level. Some software allows this.

Symptoms of too low trigger level are:

- There is a unusual high count rate with some detector and no sources present
- Left of the normal spectrum cutoff there is a significant peak right at 0keV in the energy scale

If this noise count rate and the noise peak are annoyingly high, the trigger level may be increased. It may be increased just such high, that the noise peak disappears. Further increasing of the trigger level just increases the low energy cutoff unnecessary and impairs the ability to reject pile up with low energy events.

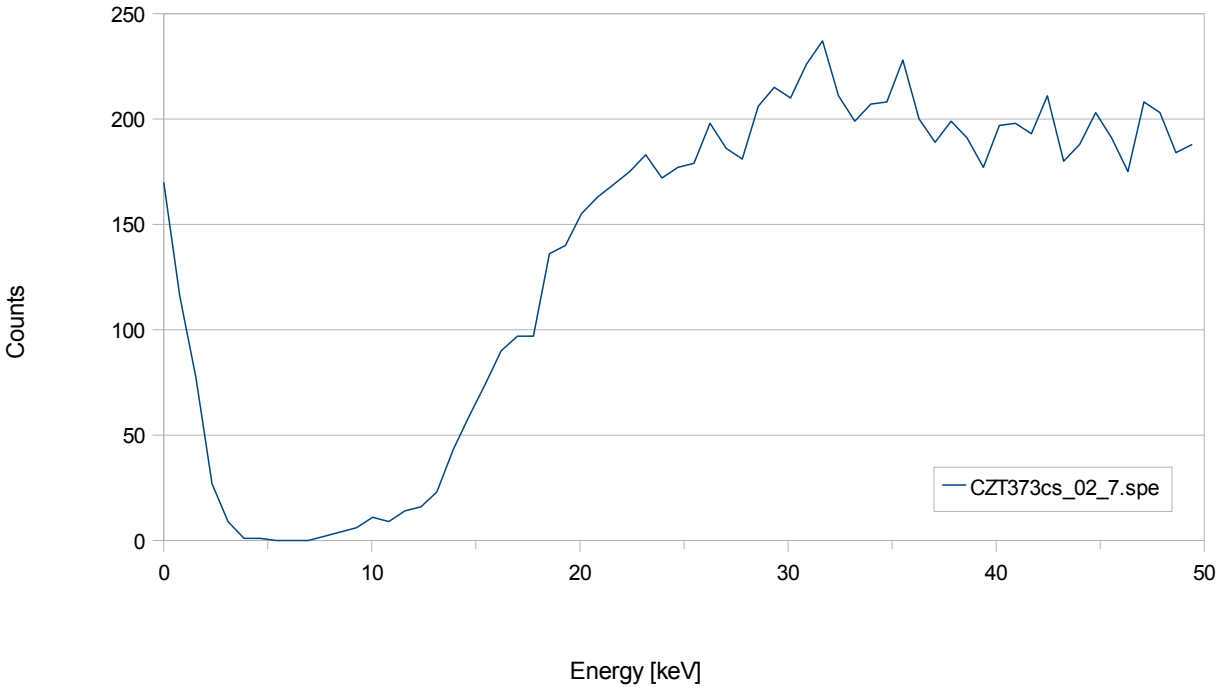


Figure 11: Lower end of a CZT spectrum. The counts left of the valley near 0keV are caused by electronical noise and a too low trigger filter

3.2.6 Pile-up Rejection

Pile-up rejection is to prevent the spectroscopical filter to be applied to events too close following each other to be evaluated properly. If there is another voltage step within the length of the filter, the energies are partially or fully added. Pile up is a problem getting increasingly worse with filter length and count rate. It can be easily seen as background right of a peak and sometimes as pile-up peak at exactly double energy.

Recognizing pile-up is task of the trigger logic. The ability to prevent pile-up depends very much on the time resolution, and therefore on the used trigger filter, see table 11.

The PUR setting is by default on, and may only be switched off for troubleshooting, checking the performance of the pile-up rejector or with some really weird preamplifier signals (overshoot or ringing).

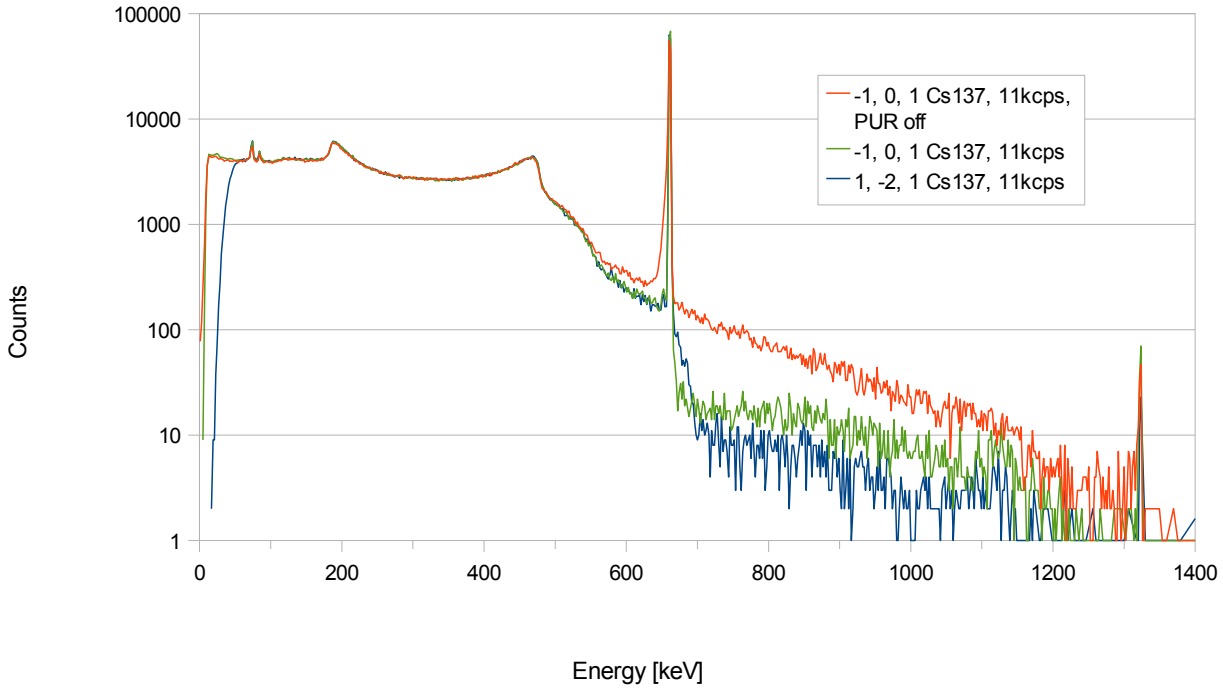


Figure 12: Effects of PUR setting on spectrum, here a Cs137 spectrum taken with 11kcps. Everything right of the prominent Cs137 peak in the middle of the spectrum is due to pile-up. The lowest pile-up component in the spectrum is achieved with the 1, -2, 1 trigger filter. The -1, 0, 1 filter is not as good in suppressing pile-up, but still much better than pile-up switched off.

3.2.7 Shaping Time

The shaping time defines the length of the spectroscopical filter, or how many values before and after the voltage step are averaged to evaluate the pulse height. The shaping time is half the rise or integration time. So, for a shaping time of 1µs 20 values before and 20 values after voltage rise are averaged. Depending on the detector and its noise spectrum, very different values can be optimum for best resolution. A long shaping time eliminates a lot of high frequency noise, but is more sensitive for low frequency noise.

For a coaxial HPGe detector the optimum is typical something like 4µs...6µs, for a CZT the best may be 0.7µs and for a NaI 0.2µs. The best shaping time to set depends also on expected count rate. For higher count rates a lower shaping time is useful, as pile-up probability and necessary processing power decreases with decreasing shaping time. Default value for shaping time is 1µs.

For MCA527L only shaping times up to 2µs are available.

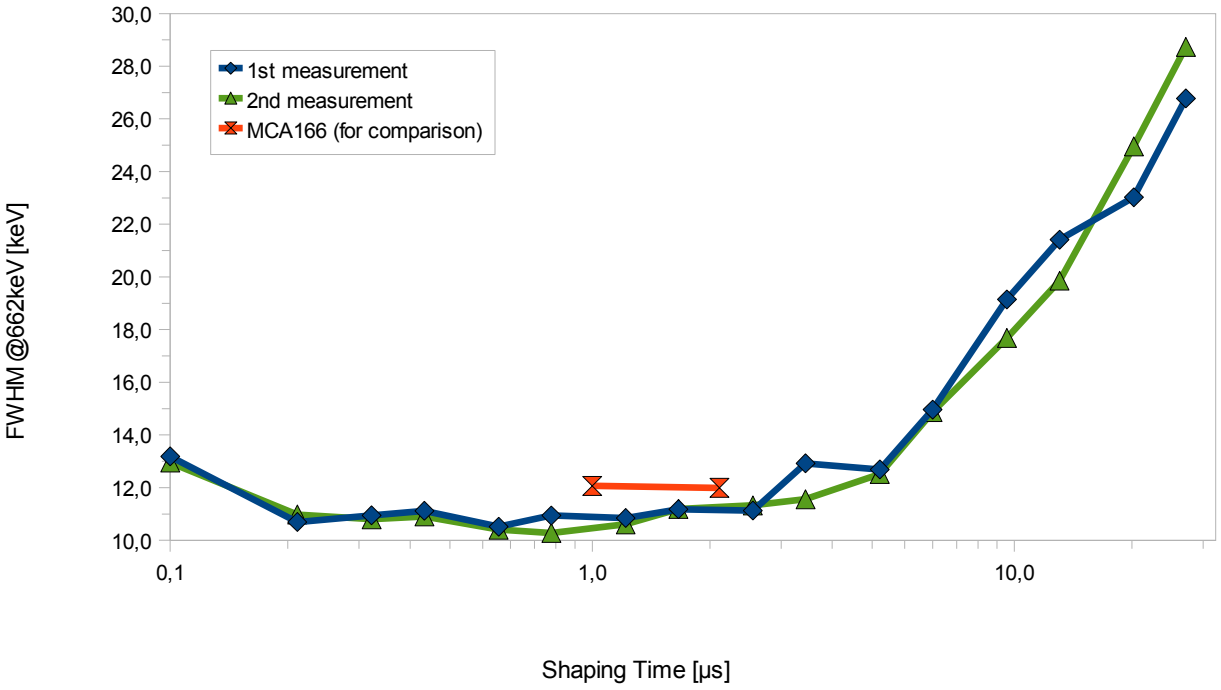


Figure 13: Dependence of resolution on shaping time for a CZT500 detector. Shaping times between 0.5µs and 1µs seem to be optimum.

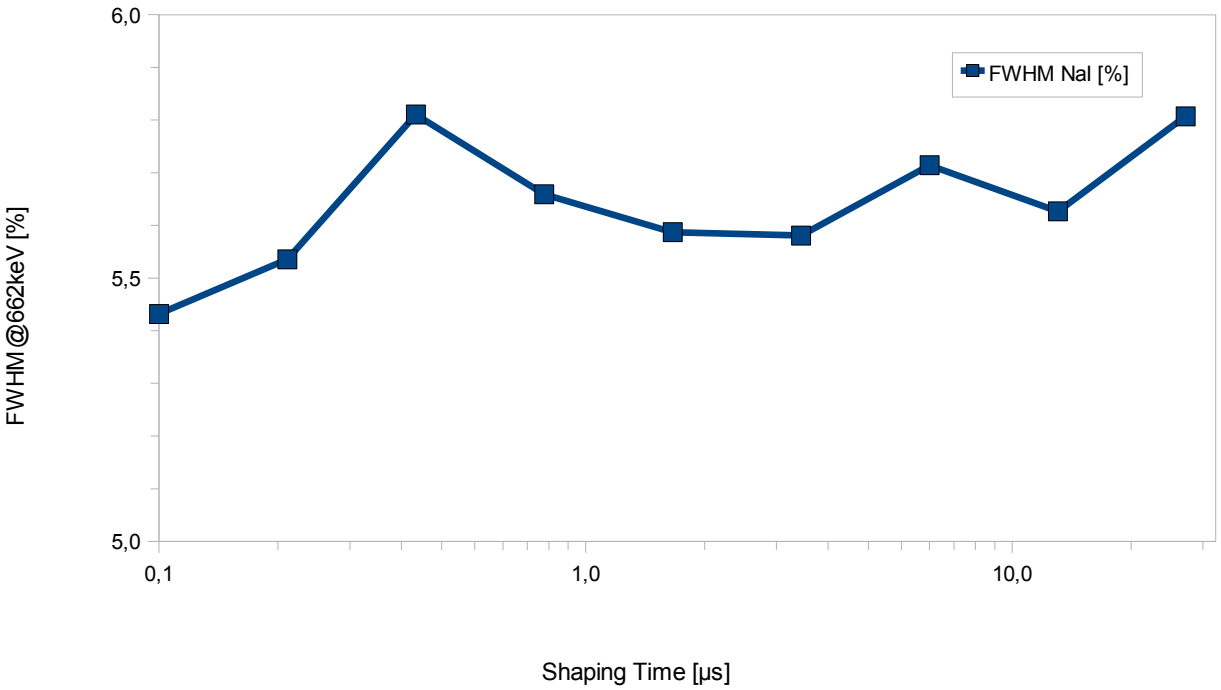


Figure 14: Dependence of resolution on shaping time for a good NaI. The shortest possible shaping time is long enough.

3.2.8 Flat Top Time

Flattop is a parameter introduced with digital multi-channel analyzers. Basically this is adjusted to the rise time of the preamplifier. Reason is that digitizing the amplitude can be done with quite high accuracy, down to 0.01% error. But the input bandwidth (3MHz) is rather high compared to the sample rate (10MHz), and so during the rise of the preamplifier signal, the value may change by 20% within 100ns and a timing jitter in this order may cause a significant error. Therefore values where the signal is rapidly changing must not be used for evaluation. See Figure 9 as an example.

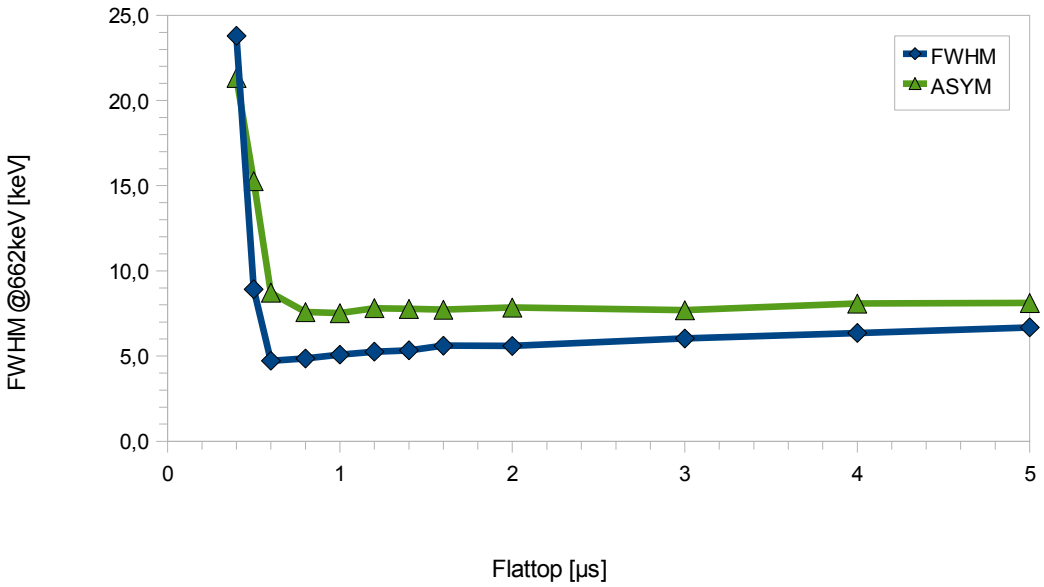


Figure 15: Resolution depending on flattop with a CZT detector. FWHM is here the Gaussian, ASYM the exponential part of the peak form.

This is adjusted with the flattop setting. As the signal to the ADC is bandwidth limited, there is a finite rise time of around 300ns even for infinitely fast rising signals, settling time may be twice as long. Therefore the shortest useful flattop time may be 0.6µs, which may be suitable for fast rise time, medium resolution detectors such as CZT. For HPGe detectors something between 0.8µs and 1.2µs may be optimum. For a NaI with a rather slow rise time something like 1.6µs may be better.

If flattop setting is too high, the spectrum will become more sensitive to low frequency noise and resolution will degrade slowly. Below a certain setting, the spectrum will degrade very rapidly. Default value for flattop is 1.2µs.

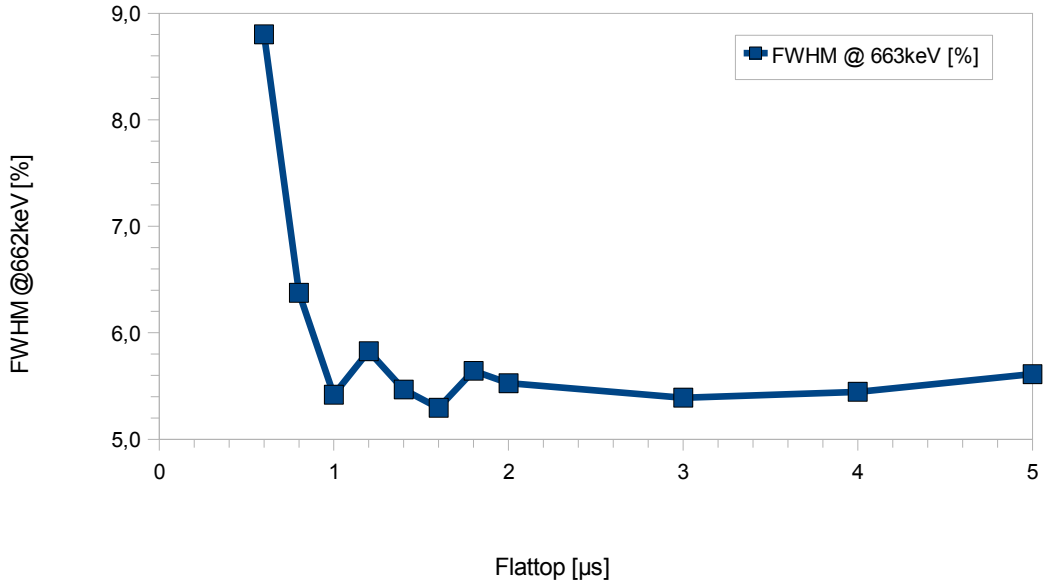


Figure 16: Dependence of resolution on flattop setting using a NaI detector. As a NaI detector exhibits slower rise times, a bit longer flattops yield best results.

3.2.9 Offset

Offset is normally set automatically. The internal offset DAC can be adjusted such that the input range goes from 0V to $+U_{max}$ or from $-U_{max}$ to 0V. Typically it is set such for positive signals the base line is at 10% of the ADC range and for negative signals the base line is at 90% of the ADC range.

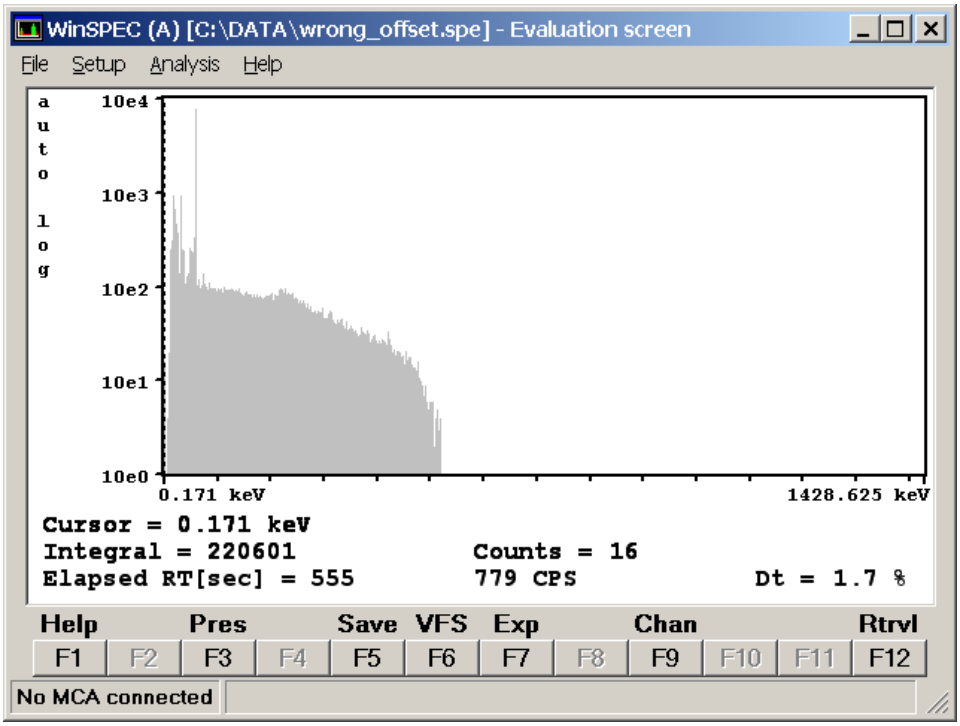


Figure 17: Spectrum with extremely wrong offset setting. The spectrum just cuts off somewhere in the middle.

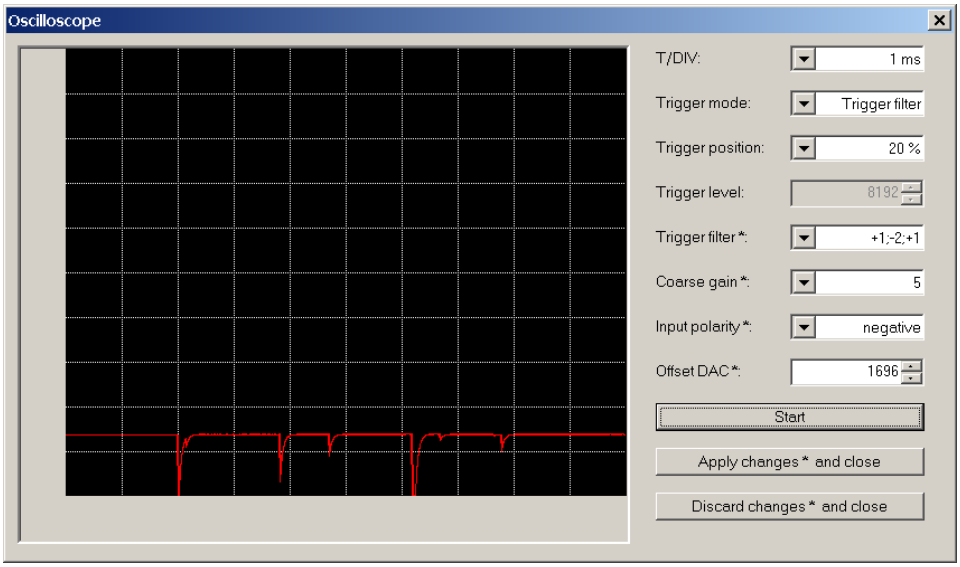


Figure 18: Wrong offset setting. The offset setting for negative signals should be at 90% and not at 14% as shown here. So it is not possible to measure high amplitude signals as they are cut off.

3.2.10 Pole Zero and Jitter Compensation

The pole zero correction is applied to make sure that a voltage step starting from the base line is evaluated with the same amplitude as signal sitting on the falling slope of a proceeding step. Without correction the slope is causing an error.

If the decay time constant of the signal is known, the slope can be easily calculated from the amplitude. In practical terms pole zero correction is achieved by adding a defined amount of DC from the input to the result. The pole zero value to be set is a value from 0...2499, for compatibility reasons the same as with MCA166. This value is proportional to the amount of DC added for correction. It is reciprocal connected with the decay time constant by:

$$t = \frac{88650\mu s}{PZC}$$

For pole zero adjustment, go to the pole zero settings window of the software. There the spectroscopical filter is applied to the signal before and after a voltage step, but where the result should be zero. The difference between those both measurements is the pole zero offset and the results are averaged over 0.8s. The pole zero value has now to be adjusted such that the pole zero offset becomes zero.

Jitter is a typical problem of digital MCA and it is caused by the fact that registered events are asynchronous to the ADC sample clock. Therefore the timing of the spectroscopical filter is always inaccurate by around 100ns. Assuming a decay time constant of 50µs, an inaccuracy of 100ns can may cause an error of 100ns/50µs=0.2%. This is unacceptable high for good spectroscopy. With some minor modifications the spectroscopical filter can

be adjusted such that a shift of the spectroscopical filter of 100ns forward or backward will not change the result. This modification is also very close connected to the decay time constant of the preamplifier and therefore there is only one adjustment parameter which adjusts both for pole zero and jitter.

Misadjustments will cause characteristic deformations of the peak shape as shown in Figure 20.

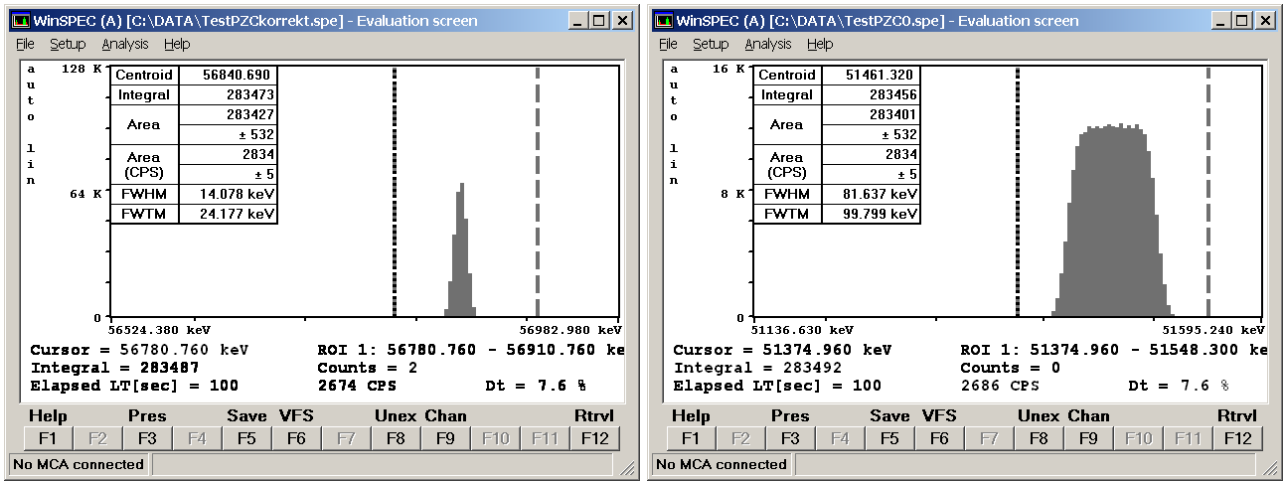


Figure 19: Measuring a periodic signal generator signal.

Left: Correct PZC setting and Jitter compensation.
Right: PCZ=0, no Jitter compensation, the jitter error gives a rectangular distribution.

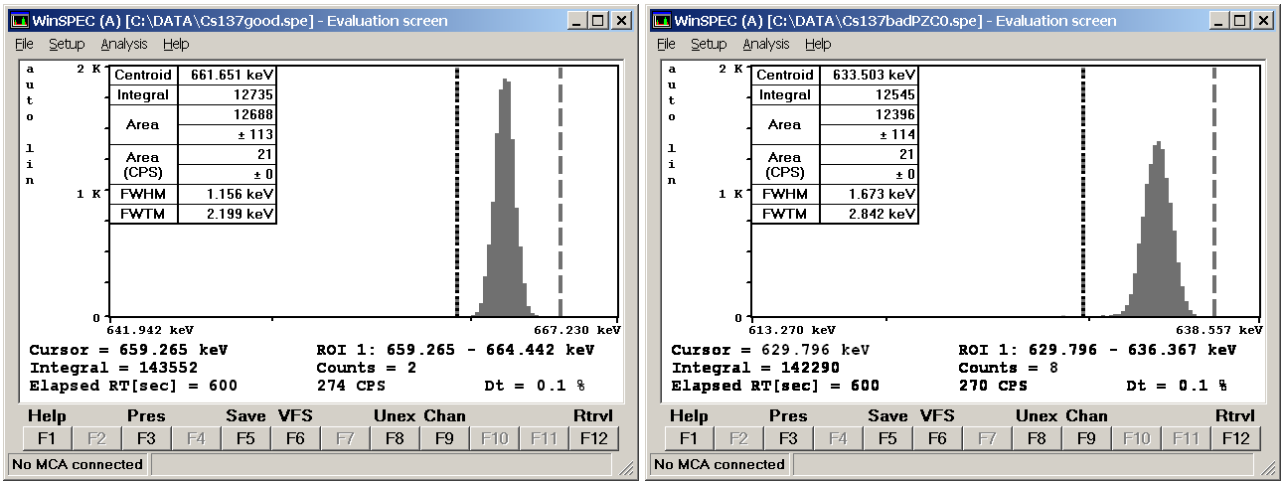

WinSPEC (A) [C:\DATA\Cs137good.spe] - Evaluation screen
File Setup Analysis Help
Centroid 661.651 keV
Integral 12735
Area 12688 ± 113
Area (CPS) 21 ± 0
FWHM 1.156 keV
FWTM 2.199 keV
641.942 keV
667.230 keV
Cursor = 659.265 keV
Integral = 143552
Elapsed RT[sec] = 600
ROI 1: 659.265 - 664.442 keV
Counts = 2
274 CPS
Dt = 0.1 %
Help Pres Save VFS Unex Chan Rtrvl
F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12
No MCA connected
WinSPEC (A) [C:\DATA\Cs137badPZC0.spe] - Evaluation screen
File Setup Analysis Help
Centroid 633.503 keV
Integral 12545
Area 12396 ± 114
Area (CPS) 21 ± 0
FWHM 1.673 keV
FWTM 2.842 keV
613.270 keV
638.557 keV
Cursor = 629.796 keV
Integral = 142290
Elapsed RT[sec] = 600
ROI 1: 629.796 - 636.367 keV
Counts = 8
270 CPS
Dt = 0.1 %
Help Pres Save VFS Unex Chan Rtrvl
F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12
No MCA connected

Figure 20: Measuring Cs137 with different PZC settings

Left: Measured Cs137 peak with correct settings. The calculated ration of FWTM/FWHM is 1.91, which is reasonably close to the 1.82 expected from a gaussian distribution.

Right: Spectrum without jitter or PZC compensation. As the jitter error has a rectangle like distribution, the FWTM/FWHM ratio is significantly smaller here and resolution is generally worse. The wrong pole zero does not really affect as the count rate is very low.

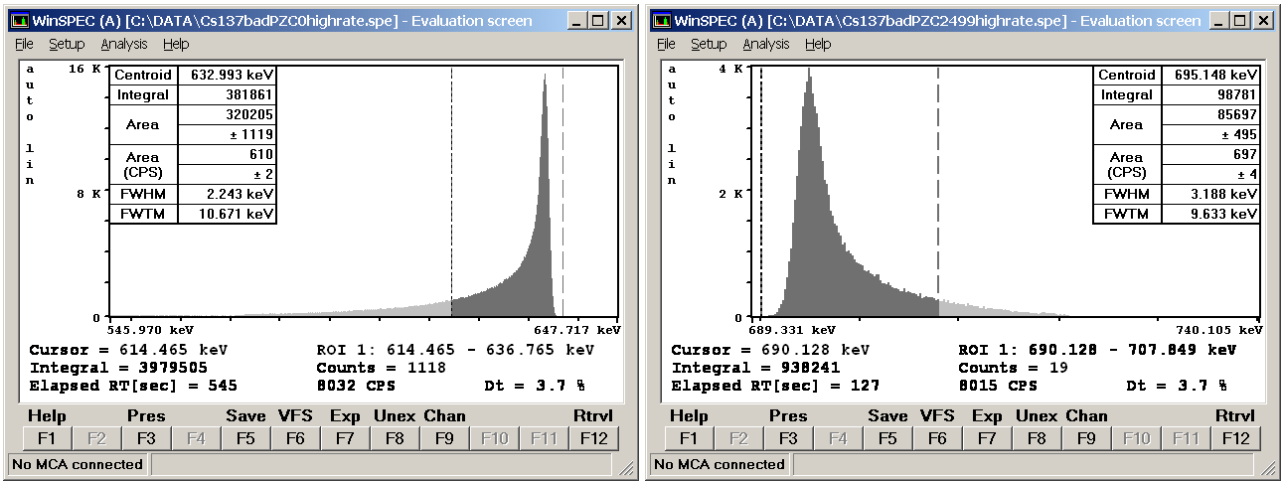

WinSPEC (A) [C:\DATA\Cs137badPZC0highrate.spe] - Evaluation screen
File Setup Analysis Help
Centroid 632.993 keV
Integral 381861
Area 320205 ± 1119
Area (CPS) 610 ± 2
FWHM 2.243 keV
FWTM 10.671 keV
545.970 keV
647.717 keV
Cursor = 614.465 keV
Integral = 3979505
Elapsed RT[sec] = 545
ROI 1: 614.465 - 636.765 keV
Counts = 1118
8032 CPS
Dt = 3.7 %
Help Pres Save VFS Exp Unex Chan Rtrvl
F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12
No MCA connected
WinSPEC (A) [C:\DATA\Cs137badPZC2499highrate.spe] - Evaluation screen
File Setup Analysis Help
Centroid 695.148 keV
Integral 98781
Area 85697 ± 495
Area (CPS) 697 ± 4
FWHM 3.188 keV
FWTM 9.633 keV
689.331 keV
740.105 keV
Cursor = 690.128 keV
Integral = 938241
Elapsed RT[sec] = 127
ROI 1: 690.128 - 707.849 keV
Counts = 19
8015 CPS
Dt = 3.7 %
Help Pres Save VFS Exp Unex Chan Rtrvl
F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12
No MCA connected

Figure 21: Measuring Cs137 with different PZC settings, jitter correction always on

Left: Wrong pole zero has the worst effect with higher count rates. Here the characteristic low energy tailing typical for under-pole-zero can be seen, and the count FWTM/FWHM ratio is very high.

Right: Too high pole zero setting causes tailing on the high energy side of the peak

3.2.11 Baseline Restoring

A disadvantage of the conventional approach of pole zero compensation by adding a DC component is that now the result becomes sensitive to DC and low frequency disturbances such as often found HPGe preamplifier offset drift. Furthermore it is desired that an energy of 0keV is found in channel 0 and the spectrum does not have offset. This is corrected by the base line restorer. The baseline restorer applies the spectroscopical filter to the signal immediately before the event if possible, and this result for the baseline is subtracted from the evaluated value for the event. The disadvantage of this is that the baseline measurement has itself an error, which adds to the total error and leads to some peak broadening. As the baseline should not change to fast, it is possible to do averaging. There are settings from 1 to 32 possible; 1 means no averaging and the baseline value always new measured, 32 is that the last measured value contributes only to 1/32 to the actual baseline.

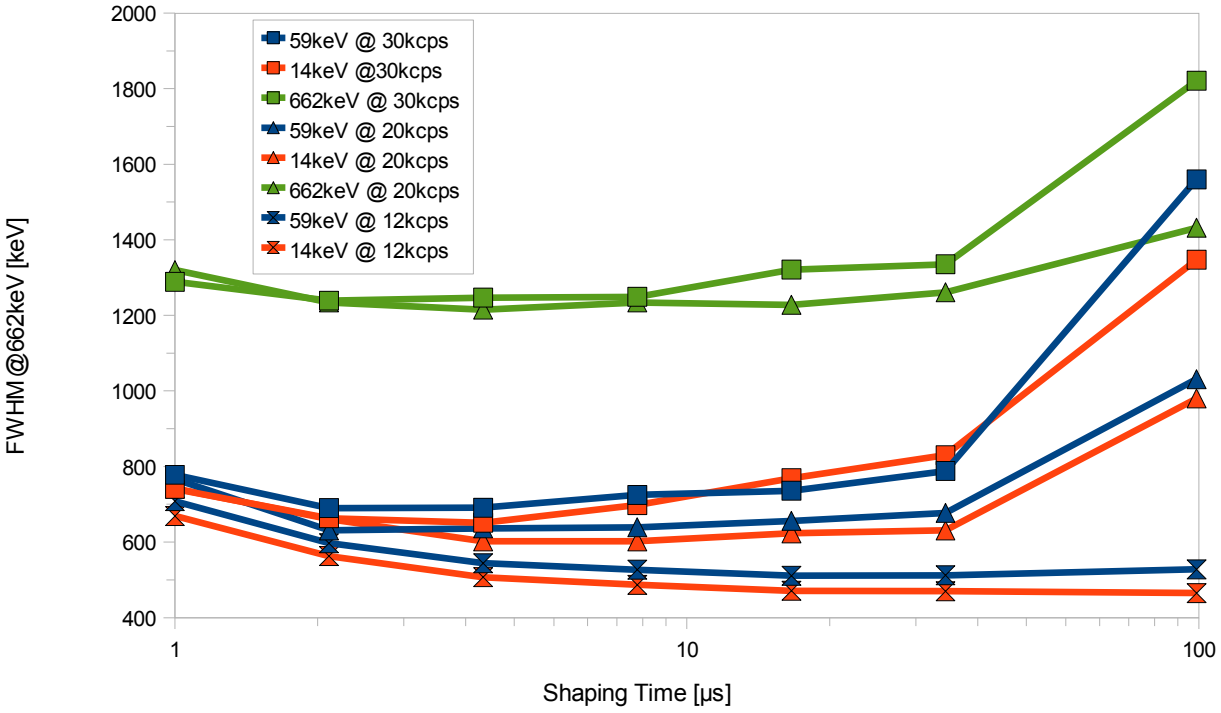


Figure 22: Dependence of resolution on base line restorer setting, as example a planar HPGe detector operating with different count rates.

Default is 16, which is best for good resolution and not too fast changing baseline. With increasing count rate and low frequency noise in the signal, smaller values down to 4 may be more optimum. For MCA527L the setting is always 4.

There is also a second very slow baseline restorer which concerns the analog part of the device and just readjusts the analog offset such that the base line is at the 10% or 90% input range of the ADC.

3.2.12 Jitter Correction

Another approach to care about the timing error problem is to use for exact timing the 1, -2, 1 trigger filter and to interpolate the zero crossing of the second derivate. This should increase the timing accuracy to something like 10ns...20ns. The amplitude is then correspondingly interpolated. Jitter correction may give a resolution improvement in some cases, but it is still experimental. Default is off, this feature is not available with MCA527L.

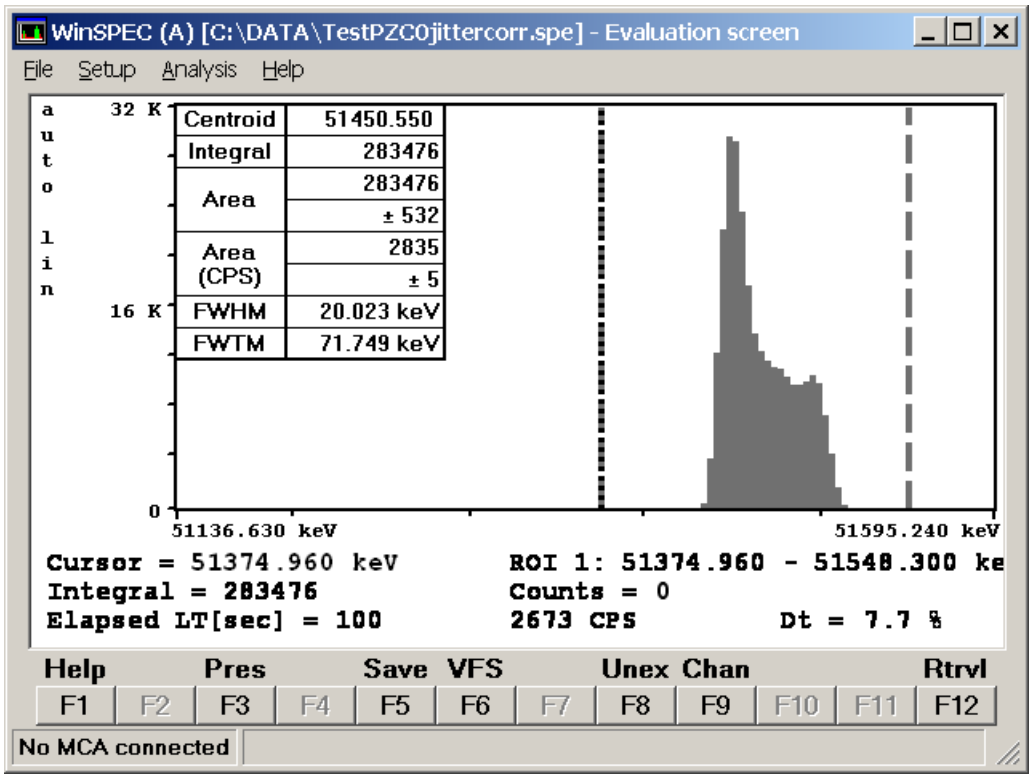


Figure 23: Measurement same as Figure 19, PZC=0 but with jitter correction.

3.2.13 Low Frequency Rejection

Low frequency rejection is a special triple differentiating spectroscopic filter for use in environments with strong low frequency noise components, e. g. microphonics with a HPGe or higher leakage currents with a CZT. Principally this filter does not only evaluate the voltage step, but also the slope of the baseline before and after the voltage step. Because of this, the low frequency sensitivity is such low that Pole zero adjustment is not necessary. However, as this filter is triple differentiating, the amount of high frequency noise is increased, even as this filter is optimized for lowest error. This filter gives best results with twice or triple as high shaping times, so throughput may be a bit limited with this. Resolution can be almost as good as with the standard filters in a quiet environment. In a noisy environment, the low frequency filter can yield orders of magnitude better results and be invaluable when forced to work in such environments. Use this option in the presence of significant low frequency interference. Default is off, this feature is not available with MCA527L.

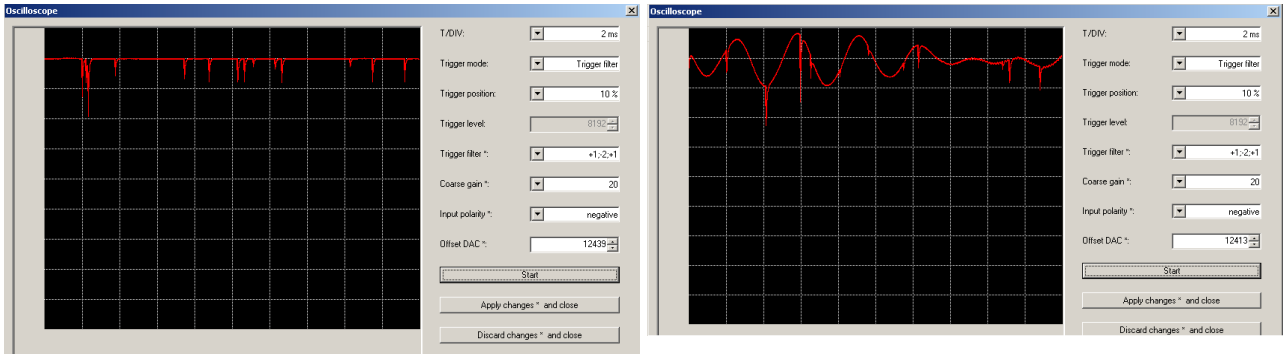


Figure 24: Preamplifier signal of a HPGe detector in a quiet and noisy environment

Left: Preamplifier signal of a HPGe measuring Am241 in a quiet environment.

Right: Preamplifier signal of a HPGe measuring Am241 in an extremely noisy environment, here a grinding machine nearby running. The signal exhibits oscillations in the 300 Hz range, which may be twice as high as the signal measured.

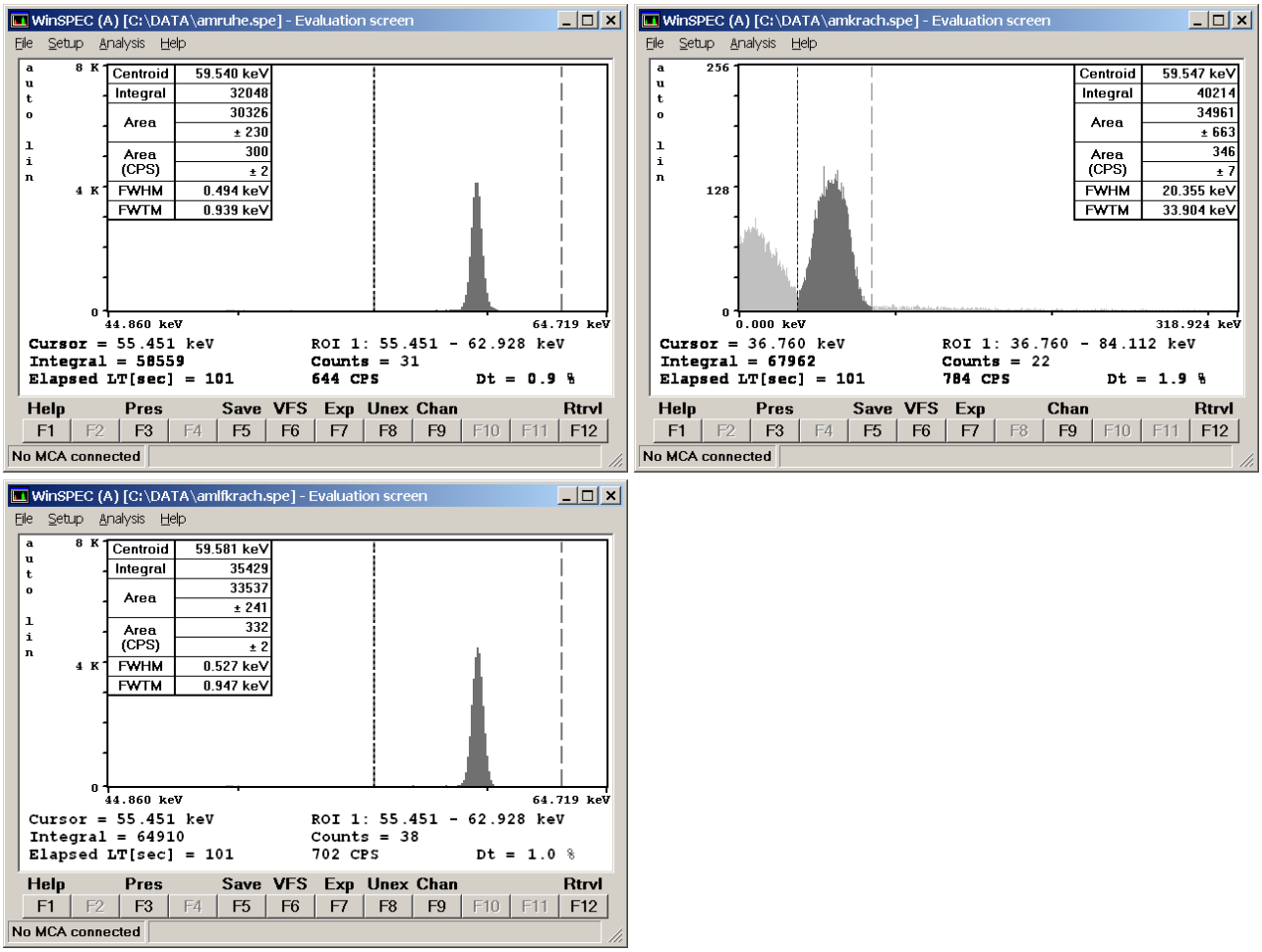


Figure 25: Effect of Low Frequency Rejection

Left: *60keV peak of Am241, measured in a quiet environment. A resolution of 0.49keV FWHM can be obtained. Settings: shaping time 6µs, flattop 0.8µs, BLR32.*

Right: *60keV peak of Am241, measured in a very noisy environment. Settings same as figure on the left. The resolution degrades from 0.49keV to 20keV, measurement is futile.*

Bottom: *60keV peak of Am241 measured in a very noisy environment, low frequency reject on, all other settings same as figure on the left.*

3.2.14 Number of Channels

The number of channels the spectrum is distributed to can be chosen between 128 and 16384 (16k). The useful setting depends mainly on the detector connected. If setting is too low, details of peaks may not be seen, if setting is too high, the statistics for a single channel is bad so the spectrum looks very noisy, and of course storage of the spectra takes more space.

A good setting for most cases is achieved if the FWHM of interesting peaks is between 3 and 8 channels.

The most useful setting when taking full range gamma spectra with a HPGe is 8k. 16K may be only beneficial when taking spectra with a good planar HPGe in a range of 3MeV, but the interest is in low energy peaks; or for electrical performance testing.

For CZT or LaBr,1024 channels are reasonable, more than 2k is not necessary. For a NaI, typically 512 channels are enough.

Default is 4k with MCA527 and 1k with MCA527L. MCA527L offers only up to 2k channels.

3.2.15 Threshold

This setting is a legacy of MCA166, where the default setting is 2% and everything below is cut away. The effect of this setting is very similar to LLD, just that here the value is in percent of the full spectrum and not in channels.

The MCA527 allows to measure much more in the low energy range. Depending on amplification and trigger filter, the low energy cutoff may be at 0.2%, therefore allowing a very high dynamic range.

Default setting is 0, but it may be a good idea to set this to 0.3%...0.5% to cut out the noise peak.

3.2.16 LLD / ULD

The LLD / ULD settings (lower level discriminator, upper level discriminator) determine, which part of the spectrum is actually counted. This setting is most useful in MCS mode for taking time dependent rate for a special part of the spectrum. In PHA mode, typically the full spectrum is counted.

Default setting for LLD is 0, for ULD it is the resolution - 1; e. g. For a 4k resolution this is 4095.

3.2.17 MCA527 Setup Examples for Use With Different Detectors

This table shall just give an overview of possible settings useful with the MCA527. It is far from being complete. For actual settings with your detector, see the detectors manual.

Table 12: Parameters for different detectors

Type	Model	Manufacturer	HV [V]	12V	-12V	24V	-24V	Input Polarity	Channels	Shaping Time [µs]	Flattop Time [µs]
CdZnTe	SDP/Z/60	Ritec	+300	x	x	-	-	neg	1024	0.8	0.7
CdZnTe	SDP/Z/20	Ritec	+500	x	x	-	-	neg	1024	0.8	0.7
CdZnTe	CZT500	Ritec	+600	x	x	-	-	pos	1024	0.8	0.7
NaI	Scintiblock	Crismatec	+500					pos	512	0.2	1.6
NaI	25825	Scionix	+550	x	x	-	-	pos	512	0.2	1.6
NaI	40*40	Amcrys-h	-800	x	x			pos	512	0.2	1.6
CsI	Sc1010	Eurorad	-	x	x	-	-	neg	256	1	
HPGe	GMX-20190-S	Ortec	-3000	x	x	x	x	neg	4096	4	0.8
HPGe	GEM 15-190	Ortec	+3000	x	x	x	x	pos	4096	4	
HPGe	GR 2018	Canberra	-3000					neg	4096	4	
HPGe	GL 0310	Canberra	-2000	x	x	x	-	neg	4096	2	
Si planar	7865S	Ortec	-1000					neg	4096		
HPGe	EGC 30-190R	Eurisys	-3000					pos	4096	4	
HPGe	EGPC 25-185	Eurisys	+2000					neg	4096	4	

Table 13: Further settings, optimized for different count rates,as example a coaxial HPGe

	shaping time	flat top	trigger filter	Base line restorer	gain	PZC
low count rate (<4kcps), optimization for best resolution and dynamic range.	4µs	0.9µs	-101	16	high coarse gain, small fine gain (0.5...1)	
general purpose, medium count rates 4-20kcps	2µs	0.8µs	10-201	8		
high count rate and throughput, input >20kcps,	1µs	0.7µs	1-21	4	lower coarse gain to avoid overrange	adjustment critical!

- Pile up rejection should be always on, except there is a preamplifier signal with overshoot and the pile up rejector rejects everything.
- Jitter correction should be always off, its an experimental feature to improve resolution.
- LF rejection should be used if there is a problem with low frequency noise (e. g. 50Hz) microphonics (machinery nearby running) or similar. If using this, increase shaping time by factor 3 at the same time.
- Input polarity setting depends on detector; if no spectrum can be seen change this; check with oscilloscope mode.
- PZC should be always adjusted

3.3 Gated Measurements

The gate input is useful if spectra should only be measured during a certain time or if certain events should be rejected, e. g. if using a Compton shield as for low radiation measurements. By software it can be set

- if gating is used or not
- what gate input level enables measurement (low or high)
- delay time. The gate level is checked an adjustable (0µs...25µs) delay time after the rise of the preamplifier signal, then the decision is made.
- Discard or sort mode. In case of sort mode, the rejected events are counted in a second spectrum. Sort mode is an option if doing stabilization with a LED pulser on a NaI detector. See also measurements with stabilization.

The gate input signal has to be TTL-compatible (3.3V nominal, but input is 5V-tolerant). An input voltage <0.8V is considered low, an input voltage >1.6V is considered high.

3.4 Measurements with Stabilization

Stabilization is an option if the gain of a detector system is not fully stable. It allows to adjust fine gain during a measurement to keep a certain peak in the spectrum at its place.

Stabilization is mostly used with temperature sensitive detectors such as NaI and for long term or series measurements.

For stabilization, a peak has to be selected from spectrum, which

- should be always present
- should be significant and not disturbed by other peaks
- is preferably in the upper part of the spectrum.

Typically peaks used would be the K40 peak (1460.5keV) which is always present in background, Am241 peaks, (gamma or alpha) as Am241 as source is sometimes integrated with NaI detectors, or a peak generated by LED light pulses, as present in special NaI detectors.

For selecting a peak, a stabilization ROI has to be selected, and a centroid to which to stabilize a peak.

If the selected peak originated from a LED light pulse, and the detector provides also a gate signal for the LED signal, gating with sort mode should be selected, and then stabilization on the gated spectrum. This causes that the stabilization light peak does not disturb the measured spectrum, and the stabilization is not disturbed by real peaks in the spectrum.

The quality of the stabilization can be influenced by the settings for stabilization area and time.

The stabilization time is the minimum time for a stabilization cycle, where fine gain is readjusted. Default is 10 seconds, and this is suitable for most cases.

The stabilization area defines the minimum counts in the area of the stabilization peak collected in a stabilization cycle before the fine gain is readjusted. The optimum value depends on the peak FWHM, peak count rate and peak drift rate. If the drift rate is high, then a rather low stabilization area is good to adjust the fine gain frequently. If drift is rather low a high stabilization area is better as then the centroid is calculated more accurate. Practical values are between 1000 and 25000. A formula to estimate the optimum area N_{opt} setting is given here[8]:

$$N_{opt} = \left(\frac{FWHM \cdot \dot{n}}{2 \cdot E \cdot \vartheta} \right)^{\frac{2}{3}}$$

where

$FWHM$ = expected width of the stabilization peak in keV

$\dot{n}$ = peak area count rate

E = energy of stabilization peak in keV

ϑ = expected drift rate for the energy calibration.

Example:

A big NaI detector shall be stabilized with the 1460keV peak from the K40 background. Within a 300 seconds measurement the 1460keV peak has an area of 3721 counts and a FWHM of 72keV. The possible detector drift is expected to be in the order of $5 \cdot 10^{-6} s^{-1}$. The optimum area setting then calculates as:

$$N_{opt} = \left(\frac{72\text{keV} \cdot \frac{3721}{300\text{s}}}{2 \cdot 1460\text{keV} \cdot 5 \cdot 10^{-6}\, s^{-1}} \right)^{\frac{2}{3}} = 1552$$

Here, setting the stabilization area to 1500 should yield the best results.

3.5 Direct Input Pulse Height Analysis

This mode is useful when dealing with Gaussian pulses which may be the output of a shaping amplifier or detector signals with a preamplifier decay time constant <40µs. However, this cannot be used with high count rates as the fast rise of a preamplifier signal is missing and pile up rejection does not work.

Furthermore, a significant part of the signal needs to be the base line, as this is required to determine peak height.

Function of this is simple. Measurement is triggered if the input signal deviates some 6σ of the base line noise. Then the algorithm checks if the signal reaches a maximum. If the maximum is reached, the 4 highest values around are averaged, subtracted by the base line average and this, multiplied by fine gain setting, is the value to be determined. After that, it waits until the base line is reached again, and the algorithm continues.

In contrary to MCA166, coarse gain and fine gain settings work here and affect the outcome of the spectrum.

8 Jörg Brutscher, “Behavior of the MCA 166 at different Temperatures and Gain settings and limits of centroid accuracy”, internal report 2001

3.6 Measurement Time Presets

For non-infinite measurements, the MCA527 offers 4 choices to limit the measurement time.

Real Time

The simplest method. The measurement will take as long a the time given. This is also the choice if doing repeat measurements.

Live Time

Often chosen if quantitative evaluation of the spectrum is done. Very similar to real time, only with high count rates live time measurements will take a bit longer than real time measurements, as live time is the real time with the dead time subtracted.

Integral

The measurement will continue until a certain number of counts in the spectrum or in a ROI are achieved. This is a choice if a certain statistics is needed in a spectrum.

Area

The measurement will continue until a certain net area of a peak is reached. This is a choice if the area of a distinct peak has to be measured with a defined accuracy.

3.6.1 Dead Time Calculation

Dead time calculation is a crucial task when doing high rate measurements and still expecting accurate quantitative measurement results.

Dead time with MCA527 has several components. At first there is the limited pulse pair resolution of the trigger filters. The pulse pair resolution (the minimum time distance between two subsequent events which is needed to count them separately) depends on trigger filter and has to be found out experimentally.

Next is the time interval which corresponds to the length of the digital filter within which no other pulses are tolerated for correct calculation. Here different subsequent pulses can be distinguished, but are rejected as pile-up.

Also the time where the input signal is out of range has to be considered as dead time. At last, also the time where the processor is busy with other tasks and cannot process events is dead time.

3.6.2 Repeat Mode

Repeat mode is basically a feature realized by software. It comprises just starting a new measurement after the previous one has finished. Number of repetitive measurements are determined by application software.

A problem for some tasks however can be that the spectrum has to be transferred to the computer before the next measurement is started. As this takes some time it may not be tolerable to some tasks, especially if measurement time is very short. For that, there exists the firmware repeat mode which allows to start immediately the next measurement while transferring the data of the previous spectrum simultaneously.

3.6.3 Autonomous Repeat Mode

Autonomous repeat mode is a still to be implemented option. As the internal data storage possibility of the MCA527 is huge and can still be extended by a microSD storage card with up to several GiB, this option allows to run the MCA527 in repeat mode without any computer connected. Data transfer will resume after computer is reconnected.

4 Multichannel Scaling (MCS)

This mode is for semi-automated measurements of time distributions with any radiation detector (HPGe, NaI, CdTe, CdZnTe and neutron counters). The software used for this is WinMCS.

It allows to measure a time distribution of count rates, and in case of a spectroscopical detector, measurement of an integral spectrum at the same time.

Input can be set to the following:

- TTL input (no spectrum possible in this case)
- Input rate (corresponds to the fast count rate of MCA measurements)
- LLD/ULD (corresponds to the content of a partial region of a spectrum, defined by the lower end LLD and the upper end ULD.

New compared to MCA166 is that the MCA527 principally supports dwell times down to 100µs, whereas the MCA166 was limited to 10ms minimum. Also the MCA527 allows up to 16k time channels, where the MCA166 was limited to 4k.

However, 100µs dwell time and 16k channels will be only supported with WinMCS versions >2.0.

5 Other and Auxiliary Measurements

5.1 Oscilloscope Mode

Oscilloscope mode is in WinSPEC-A a sub-menu of the amplifier settings menu. Its main purpose is troubleshooting; so without the necessity of an extra oscilloscope it can easily be seen, if there is a preamplifier signal present, and if it fits correctly to the MCA signal input. Compared to a regular oscilloscope, the bandwidth is with 3MHz and 10MSps rather limited, but the noise level is extremely low and measurements down to the µV level are possible.

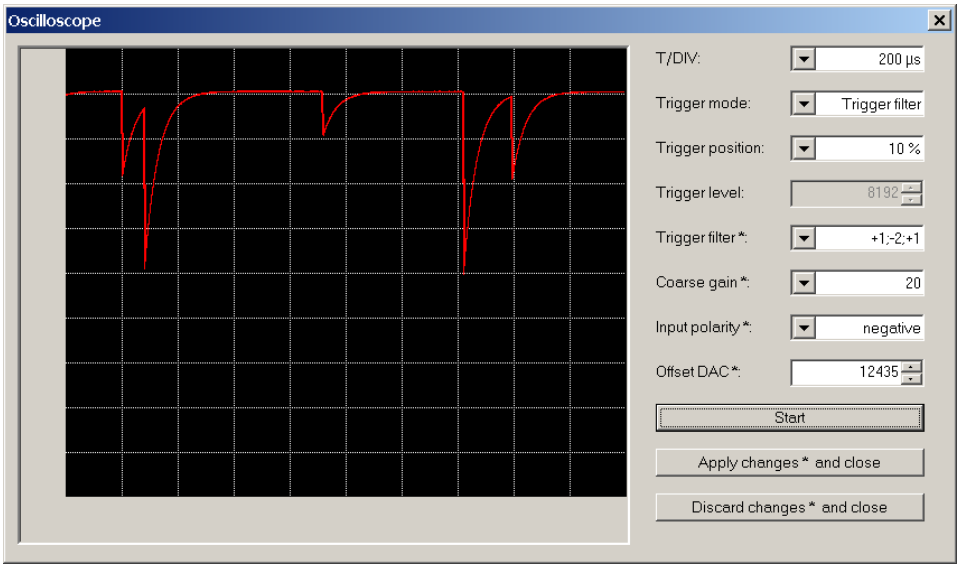


Figure 26: Typical preamplifier signal how it is seen by the MCA. Here the signal is from a planar HPGe detector.

5.2 Auxiliary Measurements

5.2.1 Supply Currents

The diagnostics menu of each program shows the primary currents of the preamplifier power supply (±12V and ±24V). This are the primary currents of the internal DC/DC-converters and not the currents that draws the detector. However, this currents can be easily calculated using the following formula:

$$I_{Out} \approx 0.8 \cdot I_{Batt} \cdot \frac{V_{Batt}}{V_{Out}}$$

The accuracy of this calculation is however limited, as 80% is just a good estimate for the efficiency of the internal DC/DC-converters.

5.2.2 Internal Temperature

The MCA527 has an on board temperature sensor to log the operation temperature of the MCA. Main purpose of this is troubleshooting and quality control in case of remote measurements. This internal temperature is shown in the diagnostics menu and it is written in saved spectrum files. It is typically 9K higher than the environmental temperature.

5.2.3 Detector Temperature

Detector temperature is an important parameter when using an NaI detector, as there the signal amplitude depends significantly on temperature. The MCA527 supports two ways of measuring temperature.

First is a digital temperature sensor with 1-wire interface, such as DS1822, connected to pin 8 of the D-SUB9 preamplifier power supply connector. If such a sensor is found, its temperature is displayed in the diagnostics menu and saved with the spectrum.

Second is a thermistor of 1kΩ nominal resistance at 25°C, connected to pin 5 of the D-SUB9 connector. The resistance of this is sensed with a calibrated current of 0.5mA, and from this the temperature is calculated.

5.2.4 Additional Analog Voltage

Pin 3 and Pin 5 of the D-SUB9 preamplifier power connector serve as slow auxiliary inputs for still not defined purposes. The input impedance is 1MΩ, the input voltage range is 0V...10V and the resolution is 11bit for every input. This voltages are displayed in the diagnostics menu and are saved with a spectrum. Pin 5 additionally has the option of a switchable 0.5mA calibrated current source and such can be used for measuring resistances.

6 Software

6.1 Overview

At the moment, only WinSPEC 2.0 and WinMCS 2.0 fully support the features which the MCA527 offers. However, all old Windows and DOS software for MCA166 can still be used with the MCA527 but not all features are available.

Furthermore, there are programs and software components to view and evaluate the measured data.

The following sections give brief descriptions of the programs. You can find more detailed information on the CD delivered together with the device. You should also use the online help of each program.

6.2 WinSPEC 2.0

First software made to support all the new features of the MCA527. Use this as default for measuring spectra.

6.3 WinMCS 2.0

WinMCS 2.0 is very similar to MCS and WinMCS. Differences are:

- Dwell time down to 100µs is supported.
- When doing LLD / ULD limited measurements or combined spectroscopical and time dependent measurements, all new amplifier, filter and channel settings are supported.

6.4 Windows and DOS software for MCA166 operating with MCA527

Numerous programs were developed to operate the MCA166. All of them serve a special purpose. There are programs for MS-DOS and Windows (32 Bit). The MS-DOS software was originally developed for the HP200LX, whose footprint was coincident with the footprint of the MCA166. The Windows programs were developed to operate the MCA166 more comfortably. The Windows programs allow to connect the MCA166-USB or MCA527 via USB cable, for the DOS software only RS232 communication is possible.

DOS as well as the DOS software is considered obsolete, but as the MCA527 will even work with this software, it is mentioned here.

6.4.1 SPEC (MS-DOS), WinSPEC (Windows)

These programs are the default programs for measuring spectra. It supports semi-automated measurements of gamma ray spectra with the MCA. The spectra are stored on mass storage media on a computer. There are two variants of WinSPEC. WinSPEC-I (for Inspectors) was designed for standard use. WinSPEC-A (for Automation) was designed for unattended measurements. Special features of WinSPEC-A are:

- Automatic restart of the program after lost of mains power, program or operating system crash
- Sending commands to a special hardware module on LPT1 for monitoring the ”State of health” (already integrated) and other states (not integrated yet)
- Writing zip files
- Data file retrieval to a flashcard
- Archiving of data files
- Writing a log file

6.4.2 MCS (MS-DOS), WinMCS (Windows)

These programs support semi-automated measurements of time distributions with any radiation detector (HPGe, NaI, CdTe, CdZnTe and neutron counters). There are two variants of WinMCS. WinMCS-I (for Inspectors) was designed for standard use. WinMCS-A (for Automation) was designed for unattended measurements. It contains the same special features like WinSPEC-A (see above).

6.4.3 U235 (MS-DOS), WinU235 (Windows)

These programs support stabilized U235 enrichment verification measurements with a NaI or CdZnTe detector (PMCN, PMCC). The algorithm bases on absolute intensity measurement of the 186keV photon energy. It also needs a two point intensity calibration with two standards.

Reevaluation / recalibration using previously recorded spectra is possible. Verification results are documented in a report file, which is automatically saved with the extension *.rep.

6.4.4 UF6 (MS-DOS), WinUF6

Similar to U235 or WinU235, but optimized for HPGe detectors. Only one intensity calibration measurement is necessary.

6.4.5 LENG

This program supports semi-automated active length measurement (HM-4) using a miniature NaI or CdZnTe detector.

6.4.6 RATE

This program supports measurements of count rates with any radiation detector (HPGe, NaI, CdTe, CdZnTe and neutron counters). In the most convenient mode of operation only the menu button "measurement" needs to be "pressed" to start a measurement and showing the count rates in form of a LCD display and a bar graph.

6.4.7 WinSCAN

WinSCAN is used for candu bundle verifications. WinSCAN is in its features somewhere between MCA and MCS. It can measure up to 500 Spectra and save them in one file. Evaluation is similar to MCS, just that there is not only an integral spectrum but one spectrum for every point so it is possible to evaluate courses off arbitrary net or integral ROI areas.

6.5 MCAtouch

Software made for safeguards purposes. The focus here is on usability and support of computers with small touchscreens and pocket computers.

6.6 Auxiliary Software for Analysis, Presentation and Miscellaneous Functions

6.6.1 Identify

Identify is an intelligent, interactive software tool to evaluate spectra. It does peak search and nuclide identification. HPGe, CdZnTe and NaI detector gamma spectra are supported. For correct peak search a starting point for the detector resolution and efficiency is assumed based on detector type and size. Features are:

- includes full master library of gamma lines (derived from table of radioactive isotopes)
- editor for creating application specific evaluation libraries
- detector function is calculated from detector data sheet, no efficiency calibration needed
- automatic determination of FWHM of the peaks found in a spectrum as function of energy

- supports 1 to 3 point energy calibration
- linear, logarithmic, square root, and double log representation possible
- error estimations/confidence assessment for identified isotopes and visualization (by overlay of calculated spectrum for a certain isotope)
- switching between English and German languages
- interactive nuclide pattern identification
- nuclide assignment suggestions also for each single peak
- instant graphical comparison to simulated spectra by clicking on a nuclide
- Windows 3.1 version also available
- IDENTIFY is not included in the MCA price
- IDENTIFY routines are also available as library for MS Windows and Linux

6.6.2 MCAPlot and MCAPrint

MCAPlot and MCAPrint are programs to view and print spectra. Up to 32 spectra can be viewed at the same time and be printed on one page. Also some evaluation functions are available. MCAPlot is not included in the MCA price. MCAPrint is a free downgraded version of MCAPlot.

6.6.3 MMCAEVAL

MMCAEVAL is a program for evaluating groups of spectra and extracting information to a MS Access style data base.

6.6.4 MCAWAND

MCAWand is a program for converting different file formats. Please note that there may be always a loss of information as not all kind of information about the spectrum is supported by every file format. The following information is converted:

- Channel Data
- Energy Calibration
- Energy Calibration points
- Live time, Real time
- Date and Time of measurement
- Spectrum Remark

The following file formats are supported for reading and writing:

Table 14: Supported file formats by MCAWAND

Source	Target
*.spe (MCA166 native)	*.spe (MCA166 native)
*.chn (Ortec)	*.chn (Ortec)
*.spe (Interwinner)	*.spe (Interwinner)
*.spc (Target)	
*.dat	*.dat (2 column: energy, channel content)
*.de1 (Canberra S100)	
*.dat (Silena Gamma 2000)	
*.spk (Röntgenanalytik)	
*.spa (Sarad)	
*.usf (URSA)	

6.7 Miscellaneous

For communication and evaluation some libraries for MS Windows and Linux are available. This may help to make own application programs or to integrate the MCA527 into an existing system.

7 Some of the Most Important Photon Energies

Table 15: Photon energies for different isotopes

Isotope	Half-life	Energy (keV)	Branching ratio (%)
Am241	432.2y	26.34/59.54	2.4/36
Cd109	462.6d	88.03	3.63
Bi214	19.9min, daughter of Ra226	609.31	46.09
Ce139	137.64d	165.86	79.87
Co60	5.271y	1173.23/1332.49	99.85/99.98
Co57	271.8d	14.4/122.06/136.47	9.16/85.6/10.68
Cs137	30.07y	661.66	85.1
Eu152	13.3.y	121.77/344.28/778.91/ 964.11/1112.07/1408. 00	28.38/26.59/12.98/14.46/ 13.57/20.85
Hg203	46.61d	279.19	81.84
Mn54	312.2d	834.82	99.98
Pb214	26.8min, daughter of Ra226	241.91/295.09/351.86	7.46/19.17/37.06
Ra226	1600y	186.11	3.28
Sn113	115.09d	391.7	64.89
Sr85	64.84d	514.0	98.4
U235	7.04E8y	143.78/163.37/185.73/ 205.33	10.53/4.7/53.15/4.7
Y88	106.65	898.04	94
Pb fluorescence x-rays	-	74.96/72.79/84.99/ 87.34	

8 Technical Data

8.1 MCA527 Hardware Specifications

8.1.1 Absolute Maximum Ratings

Exceeding anything mentioned here may damage the device!

Signal Input Voltage.....±20V
Gate Input Voltage.....-0.5V to 6.5V
Charger Input voltage.....±20V

High Voltage Output Short-Circuit Duration.....Continuous
Preamplifier Power Supply Short-Circuit Duration.....Continuous
Auxiliary Analog Input Voltage / HV inhibit (D-SUB9 Pin 5).....±30V
Auxiliary Analog Input Voltage (D-SUB9 Pin 3).....±30V
Voltage at 1-wire Interface (D-SUB9 Pin 8).....-0.5V to 6.0V
Clamp Current 1-wire Interface (D-SUB9 Pin 8).....±20mA

Input Voltage $I1_{ext}$ / RxD_{extTTL}, $I2_{ext}$ to GND_{ext}.....-0.5V to 6.5V
Output Voltage $O1_{ext}$ / TxD_{extTTL}, $O2_{ext}$ to GND_{ext}.....-0.5V to 6.5V
Clamp Current $O1_{ext}$ / TxD_{extTTL}, $O2_{ext}$ to GND_{ext}.....-50mA
Input Voltage RxD_{ext} to GND_{ext}.....±25V
Output Voltage TxD_{ext} to GND_{ext}.....±13.2V
Short-Circuit Duration TxD_{ext} to GND_{ext}.....Continuous

Input Voltage RxD to GND.....±25V
Output Voltage TxD to GND.....±13.2V
Short-Circuit Duration TxD to GND.....Continuous

Storage Temperature range.....-40°C to +85°C

8.1.2 Operational Ratings

Parameter	MCA527	MCA527L	MCA527OEM
Amplifier			
Amplifier Type	DC coupled coarse amplifier with adjustable offset		
Bandwidth (3dB)	DC to 3MHz		
Linearity	≤0.1%		
Coarse Gain Steps	2, 5, 10, 20, 50	10	10
Full Scale Input Voltage Ranges	12.5V, 5V, 2.5V, 1,25V, 0.5V	2.5V	2.5V
DC Offset Adjustment Range	-10% to 90% of full scale for positive input signals -90% to 10% of full scale for negative input signals		

Parameter	MCA527	MCA527L	MCA527OEM
ADC			
Sample Rate	10MSps		
Resolution	14bit		
Integral Non-Linearity	≤0.05%		
Temperature Stability	TK50		
Digital Signal Processing			
Trigger Filter	single and double differential trigger filters are selectable		
Pile-Up Suppression	yes		
Pulse Pair Resolution	~400ns, depending on trigger filter		
Trigger Threshold Adjustment	automated (default) and manual		
Shaping Time	0.1µs to 25µs 0.1µs steps	0.1µs to 2µs 0.1µs steps	
Flat Top Time	0µs to 5µs, changeable in steps of 0.1µs		
Fine Gain Adjustment	0.5 to 6.5, changeable in steps of 0.01%		
Channel Splitting	128, 256, 512, 1024, 2048, 4096, 8192, 16384	128, 256, 512, 1024, 2048	
Differential Non-Linearity	≤1% for 4096 channels and 1µs shaping time		
Base Line Restorer	base line restorer with adjustable averaging		
Pole Zero Adjustment	40µs to 1ms detector decay time constants can be compensated, best spectroscopic performance is achieved with 50µs decay time constant detectors		
Peak Stabilization	standard mode, LED mode, temperature mode	standard mode	
Modes of Operation			
PHA (Pulse Height Analysis)	yes		
MCS (Multichannel Scaling)	yes		
Sample Mode (Oscilloscope)	yes		
Gated Mode	yes	not available	

Parameter	MCA527	MCA527L	MCA527OEM
Spectroscopic Performance			
Resolution (FWHM) for typical 500mm^2 planar HPGe detector (count rate ≤10.000cps)	≤510eV at 1µs shaping time (Am241 source at 59keV) ≤460eV at 2µs shaping time (Am241 source at 59keV)		
Usable Spectral Range	0.13% to 100% (e. g. 3keV to 2300keV) with optimized system		
Throughput in Memory	≥75kcps at 140kcps input rate and 0.5µs shaping time ≥35kcps at 50kcps input rate and 2µs shaping time		
Preamplifier Power Supply, High Voltage Supply, Extras			
Preamplifier Power Supply[1]	±12V, ±60mA ±24V, ±60mA	±12V, ±60mA	not available
High Voltage Supply[2]	±3600V, 0.5W[3]	±1200V, 0.5W[4]	not available
High Voltage Inhibit Input[5]	available	not available	
First Auxiliary Analog Input[6]	0V to 10.23V 11bit resolution	not available	
Second Auxiliary Analog Input[7]	0V to 10.23V 11bit resolution	not available	
1-Wire Interface[8]	available, 3.3V bus voltage	not available	
Internal Temperature Sensor[9]	two sensors	not available	
Current Source[10]	500µA ±25µA 0V to 4V useable voltage range	not available	
Power Supply			
Input Voltage	9V to 14V DC		4V to 9V DC[11]
Input Power	9W max. (charging empty battery)		0.7W typical
Power Consumption	1W typ. (no detector connected) 2W typ. (detector supplied by MCA)		0.7W typical
Battery capacity	31.2Wh	15.8Wh	0Wh
Gate Input			
Input Voltage Range	0V to 5.5V	not available	not available[17]
Positive-Going Input Threshold Voltage	1.2V to 1.7V		
Negative-Going Input Threshold Voltage	0.6V to 1.0V		
Minimum Pulse Width	≤500ns		

Parameter	MCA527	MCA527L	MCA527OEM
Extension Port			
$5V_{ext}$ Output Voltage	5V ±5%	not available	not available[17]
$5V_{ext}$ Output Current	≥100mA, short circuit proof		
Data Rate $RS232_{ext}$[12]	≤1MBaud[13]		
Data Rate $RS232_{extTTL}$[14]	≤3MBaud		
Digital Output Current ($O1_{ext}$ / TxD_{extTTL}, $O2_{ext}$)	±24mA		
Digital Output Voltage ($O1_{ext}$ / TxD_{extTTL}, $O2_{ext}$)	0V to 3.4V[15]		
Digital Output Voltage High ($O1_{ext}$ / TxD_{extTTL}, $O2_{ext}$)	≥3.1V @ -100µA[15] ≥2.3V @ -24mA[15]		
Digital Output Voltage Low ($O1_{ext}$ / TxD_{extTTL}, $O2_{ext}$)	≤0.1V @ 100µA[15] ≤0.6V @ 24mA[15]		
Digital Input Voltage Range ($I1_{ext}$ / RxD_{extTTL}, $I2_{ext}$)	0V to 5.5V[15]		
Positive-Going Input Threshold Voltage ($I1_{ext}$ / RxD_{extTTL}, $I2_{ext}$)	1.6V to 2.0V[15]		
Negative-Going Input Threshold Voltage ($I1_{ext}$ / RxD_{extTTL}, $I2_{ext}$)	0.9V to 1.2V[15]		
Maximum Input Frequency at Counter Input ($I2_{ext}$)	≥20MHz		
Computer Interfaces			
USB	USB 1.1 type B socket 3MBaud	USB 1.1 type B socket 3MBaud	USB 1.1[16] type B socket 3MBaud
Ethernet	10/100MBit	10/100MBit	10/100MBit[16]
RS232	38.400Baud 115.200Baud 307.200Baud 3.000.000Baud	not available	not available[17]

Parameter	MCA527	MCA527L	MCA527OEM
Mechanical			
Dimension[18]	164x111x45 mm		136x60x18 mm
Weight	840g[19]	720g[19]	52g
Environmental			
Operational Temperature Range	0°C to 50°C with batteries -20°C to 50°C with stationary power supply		-20°C to 50°C
Humidity	≤90%, non-condensing		
Protection Class	IP42		IP00

1 All outputs are continuously short circuit proof. The total primary power must not exceed 2W!
2 Output polarity depends on module inserted (positive or negative)
3 HV3000 and HV1200 high voltage modules can be also used with limitations.
4 HV3600 and HV3000 high voltage modules can be also used.
5 Available at pin 5 of the D-SUB9 connector. Compatible to Ortec, Canberra and DFG HPGe detectors.
6 Available at pin 3 of the D-SUB9 connector. Can be used to connect different sensors.
7 Available at pin 5 of the D-SUB9 connector. Can be used to connect different sensors.
8 Available at pin 8 of the D-SUB9 connector. Can be used to connect external temperature sensors.
9 Temperature is shown in diagnostics menu and is saved with the spectrum.
10 If enabled, it feeds a constant current into pin 5 of the D-SUB9 connector. The useable voltage range allows to measure resistance in the range of 0Ω to 8kΩ.
11 Works down to 3.2V but RS232 and USB interfaces are not functioning.
12 $RS232_{ext}$ means the interface RxD_{ext} / TxD_{ext} which is a true RS232 transceiver.
13 Maximum data rate depends on load and cable quality. Real data rates may be significant lower!
14 $RS232_{extTTL}$ means the interface RxD_{extTTL} / TxD_{extTTL} which is a logic level RS232 transceiver. Because both signals are inverted internally, any externally connected UART must invert both signals, too!
15 Referred to GND_{ext}.
16 Available as option.
17 Possible for custom specific version.
18 Without connectors.
19 Including batteries and high voltage module.

8.2 Block Diagram of the MCA527

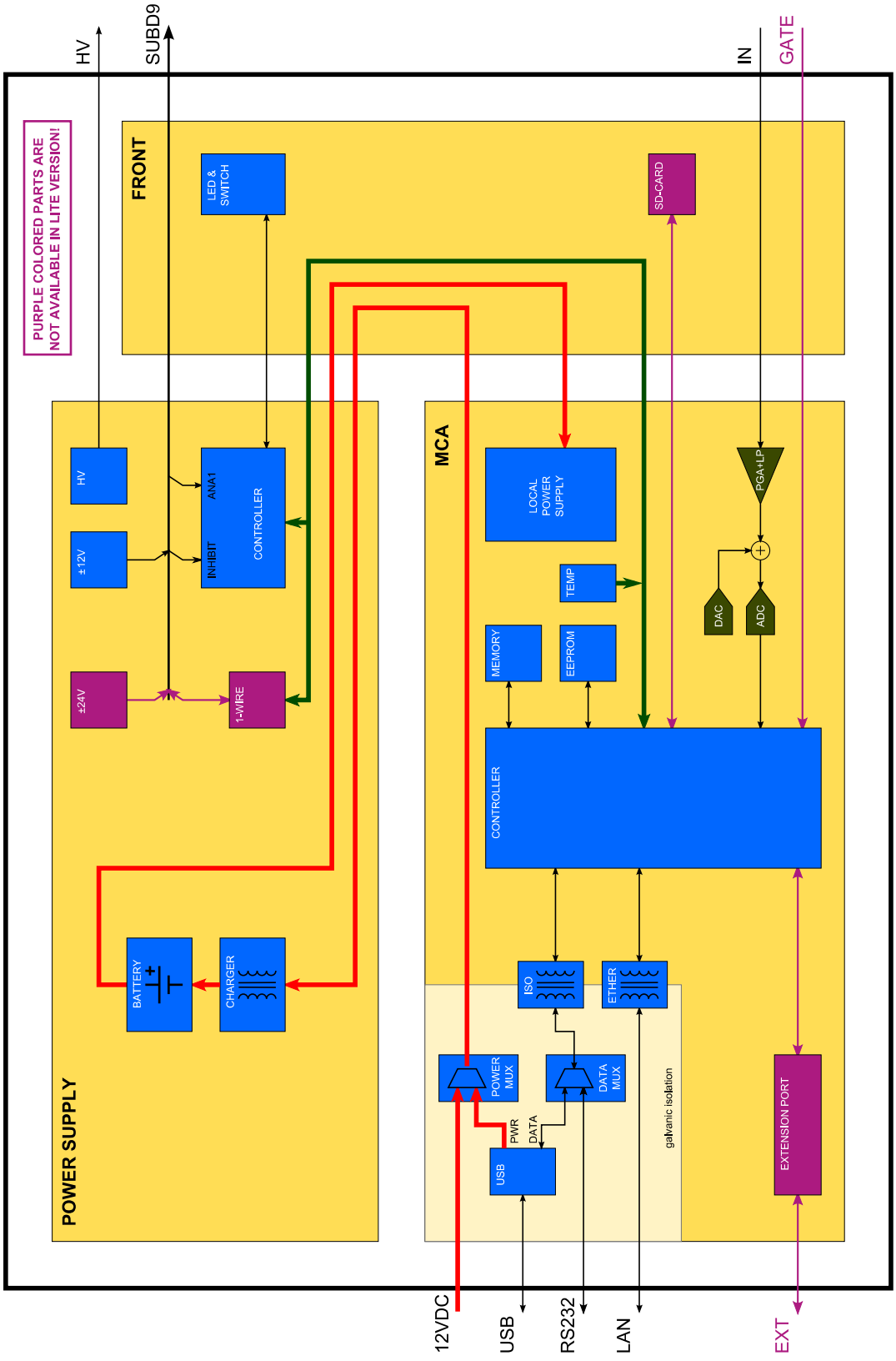


Figure 27: MCA527 Block Diagram

9 Troubleshooting

General Remark:

Before changing anything concerning the hardware, plugging or pulling cables etc. shut down the high voltage and switch off the MCA.

Soldering or manipulating with the SMD boards is strongly not recommended for users. We have specialists for that. If you have a problem which cannot be solved by the table below, contact us. If it is really a hardware fault, we can repair this for a fair price.

1. Software tells "MCA not connected!"
   - Switch on the MCA
   - Check cable between MCA and Computer. Serial cable may be loose or not connected. Connect cable correctly
   - Try another cable.
   - Check MCA battery. Charge MCA battery
   - The MCA is not recognized (”MCA not connected”) running MCA DOS Software in a DOS Box on Notebooks
   - Disable Power Save Mode for COM Port
   - Try another interface
2. MCA lamp does not flash regardless if the switch is on or off
   - MCA battery empty. Charge MCA battery.
3. MCA lamp flashes irregularly, Computer tells "MCA power failure" or beeps
   - MCA battery very low. Charge MCA battery.
   - MCA internal or communication error. Switch off and on MCA, restart software.
4. Power Supply Error: Go to Diagnostics, Measurement is not possible

   Go to diagnostics, blinking power supply currents indicate overload, check also the battery voltage.
   - MCA battery very low. Charge MCA battery and switch on HV and preamplifier supplies again.
   - Short circuit in detector? Check if detector is defective. Disconnect detector, try again. (Do not pull or plug connectors when MCA is on!) Change detector.
   - Too power-hungry preamplifier. A fully charged MCA battery may help sometimes. Otherwise you have to exchange the preamplifier.
   - If the diagnostics menu shows irregular high currents or even overload although there is no detector connected to the MCA and the battery voltage is ok, there may be a fault in the internal power supply. Contact GBS for repair.

5. The threshold of the spectrum seems to be much higher than expected.
   - If the lower cutoff rises by itself, this is most probable caused by the auto threshold circuit which is responsible for detecting the noise level and adjusting the threshold to it. Check for excessive noise in the system.
6. The high energy part of the spectrum is reduced or even missing.
   - This may be a problem with high count rates and high coarse gain settings. Please check the preamplifier signal with the oscilloscope mode: Is the base line correct at 10% (or 90% for negative signals)? Does the signal fit into the oscilloscope window or does it overflow very often? In such cases, reduce coarse gain and readjust offset if necessary.
   - Check if the behavior changes if the pile up rejector is switched off. Check the signal from the preamplifier. If the preamplifier signal rise time is slower than 500ns, then there is the danger that regular pulses (especially the large ones) are misinterpreted as pile-up. The same may happen if the preamplifier signal exhibits overshoot or ringing. Try to use another preamplifier or just switch the pile-up rejector off.
   - Similar effects can be seen if detector cables longer than 50m are used.
7. Dead time shown is very high although the count rate is low.
   - Count rate may be extremely high so that the MCA is overloaded.
   - Preamplifier signal is out of range most of the time. Check with oscilloscope window, reduce coarse gain, readjust offset.
   - Electronic noise in the system.
8. Too high background rate with BICRON detectors
   - Set Fast Threshold to 600 (You have to edit a setup file with a text editor for this) for gain > 50 (Edit setup file)
9. Everything should be okay, but the MCA gets no signals or just measures strange spectra
   - wrong input polarity. Check input polarity, just toggle it for a test.
   - The amplification is severely wrong set.
   - wrong input mode. Check also ADC input mode
10. Very bad resolution in a HPGe spectrum
    - Check settings: Pole zero, shaping time, flat top.
    - Detector worn out or defective. Change and regenerate detector.
    - Problems with the high voltage module. Try another high voltage module.
    - Check cables. Keep them away from switch mode power supplies and other possible sources of electromagnetic noise.
    - In case of low frequency interference: Try BLR setting =1 or LF reject.

11. Bad resolution in a HPGe spectrum or from a test generator, specially at high amplification factors
    - Check electrical noise and EMC compatibility of surroundings. Some laptops and also some switch mode power supply battery chargers may disturb. Remove all connections from the MCA to ground or to mains voltages. Try a different computer / laptop / palmtop.
    - Winding the cable to the detector / computer several times around a ferrite ring also may help
12. While opening a spectrum, the MCA program tells "Wrong data format" or "data format error"
    - spectrum was created by another program or another program version. Check results, just ignore.
13. too high count rate
    - Keep a bigger distance to radiation source. Try a less sensitive detector. Watch for your personal safety!
    - Check detector
    - Check for disturbances of switch mode power supplies etc.

Typical errors which may be observed with the detector preamplifier signal are:

- Rise time is too slow. This may cause degraded resolution in some cases. Increase flattop time.
- The fall time is too fast (time constant resp. 1/e fall time < 40µs). This causes that the pole-zero setting cannot be correctly adjusted. Consequences may be peak shift and peak broadening with higher count rates. Try direct input or try to use another preamplifier.
- Preamplifier signal exhibits ringing: This may trigger the Pile up rejector and lead to missing parts of the spectrum. Try a different trigger filter or switch PUR off.
- LF noise on the base line: Try BLR setting =1 or LF reject.

A MCA527 Algorithm, Formulas

This appendix lists the algorithms used by the MCA for the following functions:

- Area, Area uncertainty
- Centroid
- FWHM
- Smooth
- Strip
- Energy Calibration

The Area and the Area Uncertainty Function:

The area algorithm calculates the number of counts above the background in a ROI. The background area is determined by averaging 4 points on both sides of the peak (the ROI limit points and 3 outer points) and linear fit:

$$Area = Integral - Background$$

$$Background = \frac{ROI_{end} - ROI_{begin} + 1}{8} \left(\sum_{i=ROI_{begin}-3}^{ROI_{begin}} Spectrum_i + \sum_{i=ROI_{end}}^{ROI_{end}+3} Spectrum_i \right)$$

$$Integral = \sum_{i=ROI_{begin}}^{ROI_{end}} Spectrum_i$$

$$Area\ Uncertainty = \sqrt{Integral + \left(\left(\sum_{i=ROI_{begin}-3}^{ROI_{begin}} Spectrum_i + \sum_{i=ROI_{end}}^{ROI_{end}+3} Spectrum_i \right) \left(\frac{ROI_{end} - ROI_{begin} + 1}{8} \right)^2 \right)}$$

where

$Spectrum_i$	= the absolute number of counts in channels i
ROI_{begin}	= the ROI's start channel
ROI_{end}	= the ROI's stop channel
i	= channel number

Centroid:

The peak centroid is the sum of the channel contents[9] times the channel number divided by the sum of the channel contents in the range of the channels above the half maximum:

$$Centroid = \frac{\sum_{i=l}^{h} i \cdot Spectrum_i}{\sum_{i=l}^{h} Spectrum_i}$$

where

i	= channel number
l	= lowest channel above the half maximum
h	= highest channel above the half maximum
$Spectrum_i$	= net contents of channel i

FWHM:

The Full Width at Half Maximum (FWHM) is the background corrected peak's width at one-half of its maximum amplitude. The algorithm first proceeds down one side of the peak until it finds a channel (e. g. 1203) whose counts fall below the half maximum channel. It is now made sure that the following channel (e. g. 1204) also falls below the half maximum channel. The same algorithm is applied for the other side of the peak. The left and the right FWHM points are the interpolated channels between the counts of the channel below and above the half maximum value.

Smooth:

Smooth averages the current spectrum (the original data will be overwritten) using a binomial formula:

3 point smoothing:

$$Spectrum_i' = \frac{Spectrum_{i-1} + 2 * Spectrum_i + Spectrum_{i+1}}{4}$$

5 point smoothing:

$$Spectrum_i' = \frac{Spectrum_{i-2} + 4 * Spectrum_{i-1} + 6 * Spectrum_i + 4 * Spectrum_{i+1} + Spectrum_{i+2}}{16}$$

where

$Spectrum_i$	= the original contents of channel i
$Spectrum_i'$	= the smoothed contents of channel i

9 background corrected

Strip:

Strip subtracts a specified fraction of the spectrum. The Strip factor can be “positive“ or “negative“ :

$$Spectrum'_y = Spectrum_y - F * Spectrum_x$$

where

$Spectrum'_y$	= Count content of channel i in the resulting spectrum
$Spectrum_Y$	= Count content of channel i in the original spectrum
$Spectrum_x$	= Count content of channel i in the spectrum to be subtracted
F	= Strip factor

E-calibration:

The Energy calibration allows to convert the x-axis channel numbers into energy values in KeV. The following formula is used:

$$E = S * Channel + O$$

where

S	= slope
O	= offset
$Channel$	= channel number

The coefficients can be set as numeric values or by linear fit of two energy channel/peak centroid pairs.

B Further documents

The further documents are not intended for ordinary users but for developers and users which need more information about the MCA527. The further documents do not exclusively refer to the MCA527.

- MCA Spectral Data Format
  MCA_Spectral_Data_Format_XXXX_XX_XX.pdf

- Description of the MCA527 Firmware Commands
  MCA527_Firmware_Commands_XXXX_XX_XX.pdf

- Description of the MCA Communication DLL
  MCA_Communication_DLL_XXXX_XX_XX.pdf

- Use of MCA User Data Memory by Specific Applications
  MCA_User_Data_XXXX_XX_XX.pdf

- Description of the MCA527 Oscilloscope Mode
  MCA527_Oscilloscope_Mode_XXXX_XX_XX.pdf

- MCA Binary Data Format
  MCA_Binary_Data_Format_XXXX_XX_XX.pdf